Regional Dynamic Model and Statistical Techniques: California Climate Certainties and Uncertainties

N.L. Miller[1,2], N.J. Schlegel[2,1,], P.B. Duffy[3], D.R. Cayan[4,5], H. Hidalgo[4], J. Jin[6,1], H. Kanamaru[4], M. Kanamitsu[4], T. O'Brien[7], L.C. Sloan[7], M.A. Snyder[7], K. Yoshimura[4]

[1]*Berkeley National Laboratory*
[2]*University of California, Berkeley*
[3] *Climate Central and Livermore National Laboratory*
[4] *University of California, San Diego*
[5]*U.S. Geological Service*
[6] *Utah State University, Logan*
[7] *San Diego University of California, Santa Cruz*

Sponsor: CEC – PIER Climate Change Scenarios Program Manager Guido Franco

Outline

- Regional Downscaling Techniques for the California Assessments
- Intercomparing Downscaling Strengths and Weaknesses
- Quantification of Variables, Fluxes, and Time-Series
  - Temperature and Precipitation
  - Wind Magnitude and Direction
  - Pressure and Geopotential Height
  - Model Performance Summary
- Preparing the Climate Change Scenarios for the 2010 Assessment
- Next Steps and Concluding Remarks

Dynamic and Statistical Downscaling Methods

- Dynamic downscaling is a numerical weather prediction with complete meteorological equations resulting in most weather, and climate, variables and fluxes.

- Statistical downscaling is based on coarse-resolution predictors that lead to high-resolution predictands for *temperature and precipitation*.

- Dynamic downscaling requires a large amount of computational and data storage resources.

- Statistical downscaling is computationally inexpensive and many representations can be generated quickly.

Approach

Downscaling Groups: Three Dynamic and One Statistical

- Berkeley Lab and UC-Berkeley: Miller, Schlegel, Jin

NCAR Weather Research and Forecasting Model with

(1) Rapid Update Cycle (WRF-RUC)

(2) Community and Model version 3 (WRF-CLM3)

- UC-Santa Cruz: Sloan, Snyder, O'Brien

ICTP Regional Climate Model Version 3 (RegCM3)

- UC-San Diego: Kanamitsu, Yoshimura, Kanamaru

NOAA Regional Spectral Model (RSM)

- UC-San Diego: Hidalgo, Dettinger, Cayan

Constructed Analogues Statistical Model (CANA)

Dynamic Model Land Surface Features

	Vegetation	Soil	Snow	Lake	River-Routing
WRF-CLM3	Up to 10 vegetation types in one grid Dynamic vegetation	10-layer soil Frozen soil	5-layer snow Liquid water within snow Variable snow density	10-layer lake Snow and ice on the lake included	A simple digital elevation model (DEM) to calculate water flow directions
WRF-RUC	One vegetation type in one grid cell NO Dynamic vegetation	6-layer soil Frozen soil	2-layer snow No liquid water within snow Fixed snow density	N/A	N/A
RegCM3-BATS	One vegetation type in one grid cell NO Dynamic vegetation	3-layer soil No Frozen soil	1-layer snow No liquid water within snow Fixed snow density	Hostetler lake model	N/A
RSM-Noah	One vegetation type in one grid cell NO Dynamic vegetation	4-layer soil	1-layer snow No liquid water within snow Fixed snow density	N/A	N/A

Constructed Analogues Statistical Technique (CANA)

Key assumptions:

- Future climate patterns can be derived from linear combinations of the weather from a library of past observations.
- Coarse-resolution models are correct at fine-scale resolutions as well.

- Advantage - CANA downscaling techniques does not require specific climate forcing.
- Disadvantage - CANA assumes stationarity and will not capture significant changes in climate forcing.

The Importance of Model Intercomparisons

- Intercomparisons provide quantitative evaluations of model and process performance compared to observations and other models.

- Intercomparisons are essential for understanding how model simulated projections of the future compare with the present.

- Intercomparisons allow for model advancements, leading to reduced errors, and improved model predictability.

- Improved model predictability will allow for *better decision making* of actions needed for climate change mitigation, adaptation, and coping strategies.

Model Standards for Intercomparing

- Each RCM was required to generate a 10 year historical simulation, 1 January 1980 to 31 December 1989.

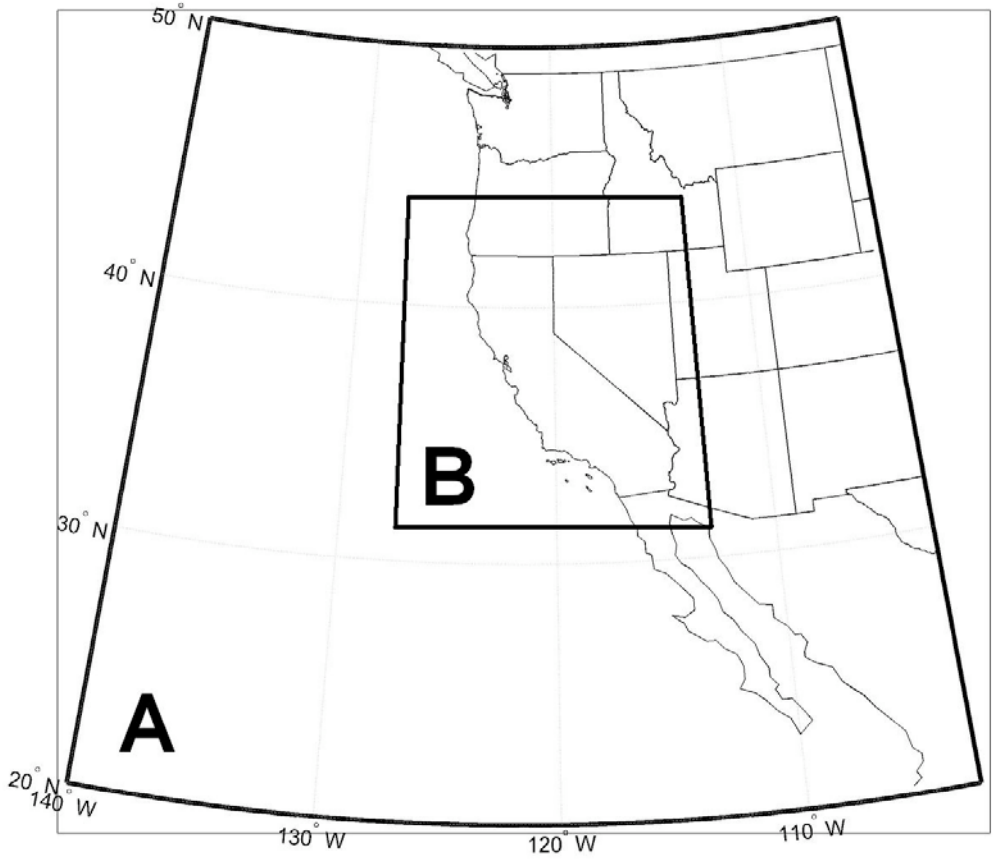
- Each RCM used the same set of double nested domains and resolutions (A) western U.S. at 30-km and (B) CA at 10-km.

- Each RCM used the same set of external forcing, the NCAR/DOE Reanalysis II dataset for Initial and Lateral Boundary Conditions.

- Sea Surface Temperature (SST) updating was based on the AMIP Dataset, except for RSM which used the European Reanalysis 40 year dataset (ERA40).

- Each model saved a common set of specified varies, fluxes, mapped these onto common grids for analysis and followed the PCMDI protocols for IPCC AR4 Intercomparisons.

Model Domains and Resolutions

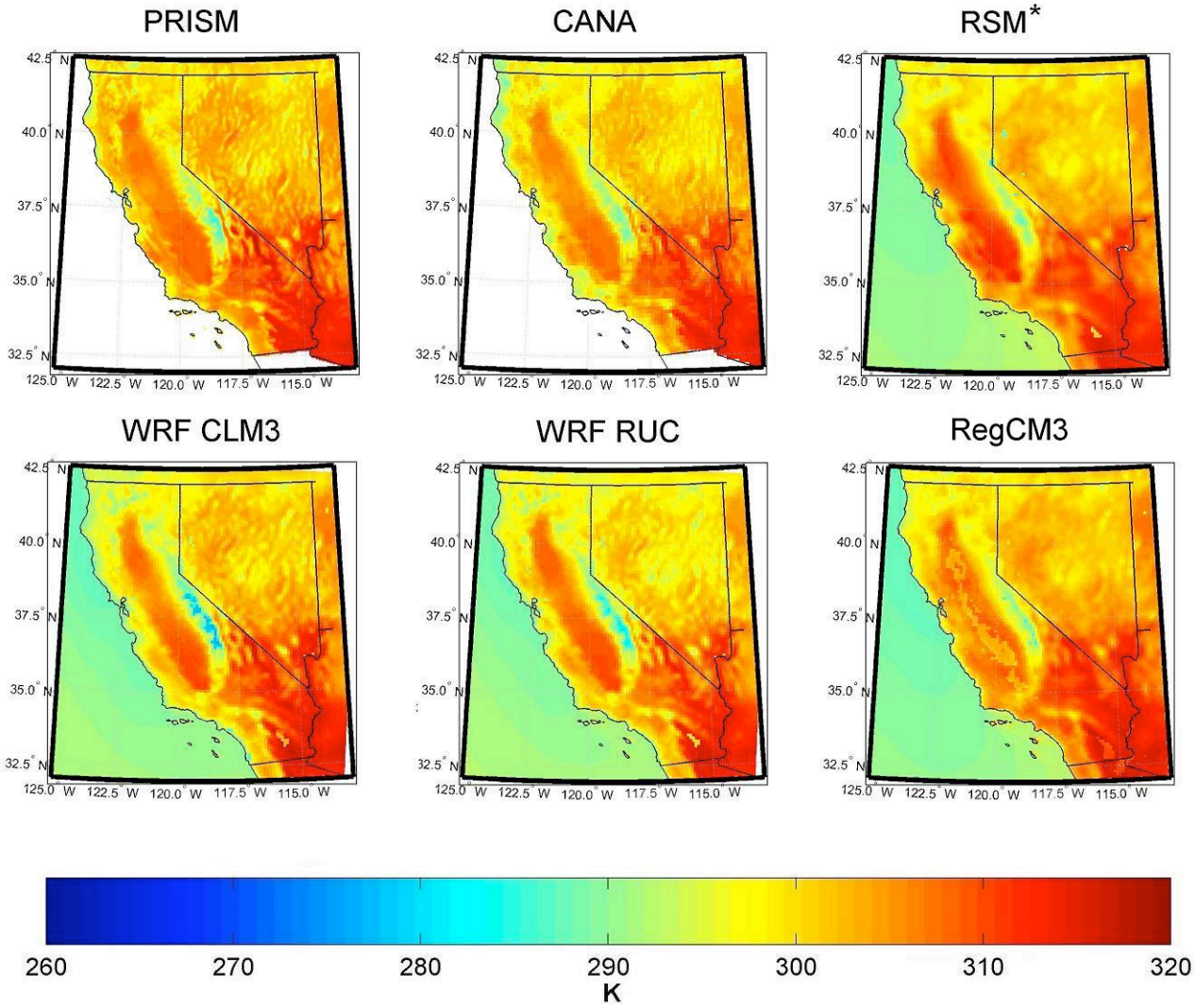


A - Western U.S. and Eastern Pacific Ocean, 30-km resolution, [139W21N x 104W51N]

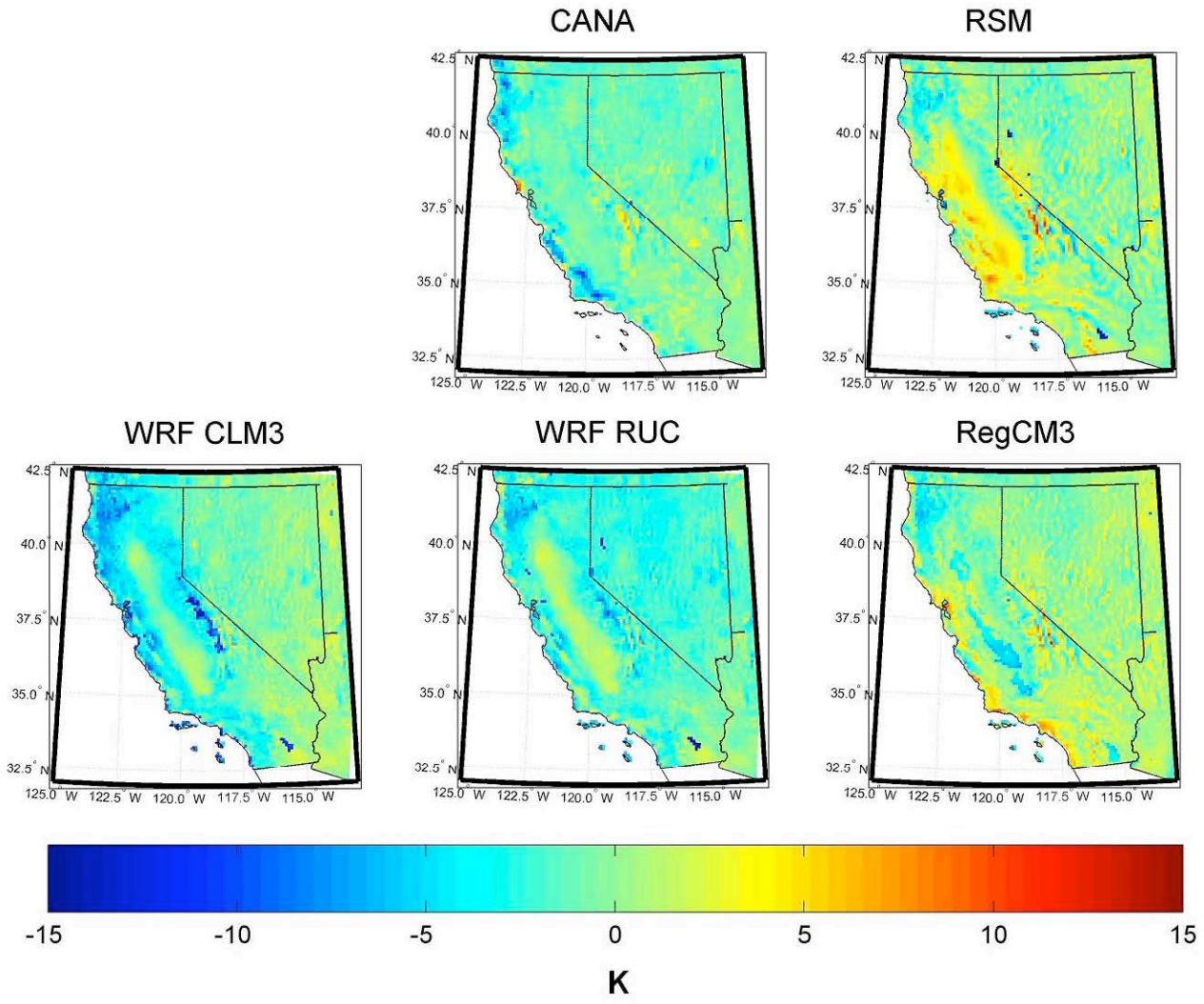
B - California, Nevada, Eastern Pacific Ocean, 10-km resolution, [128W31N x 113W44N]

Summer Maximum Temperature

June - August

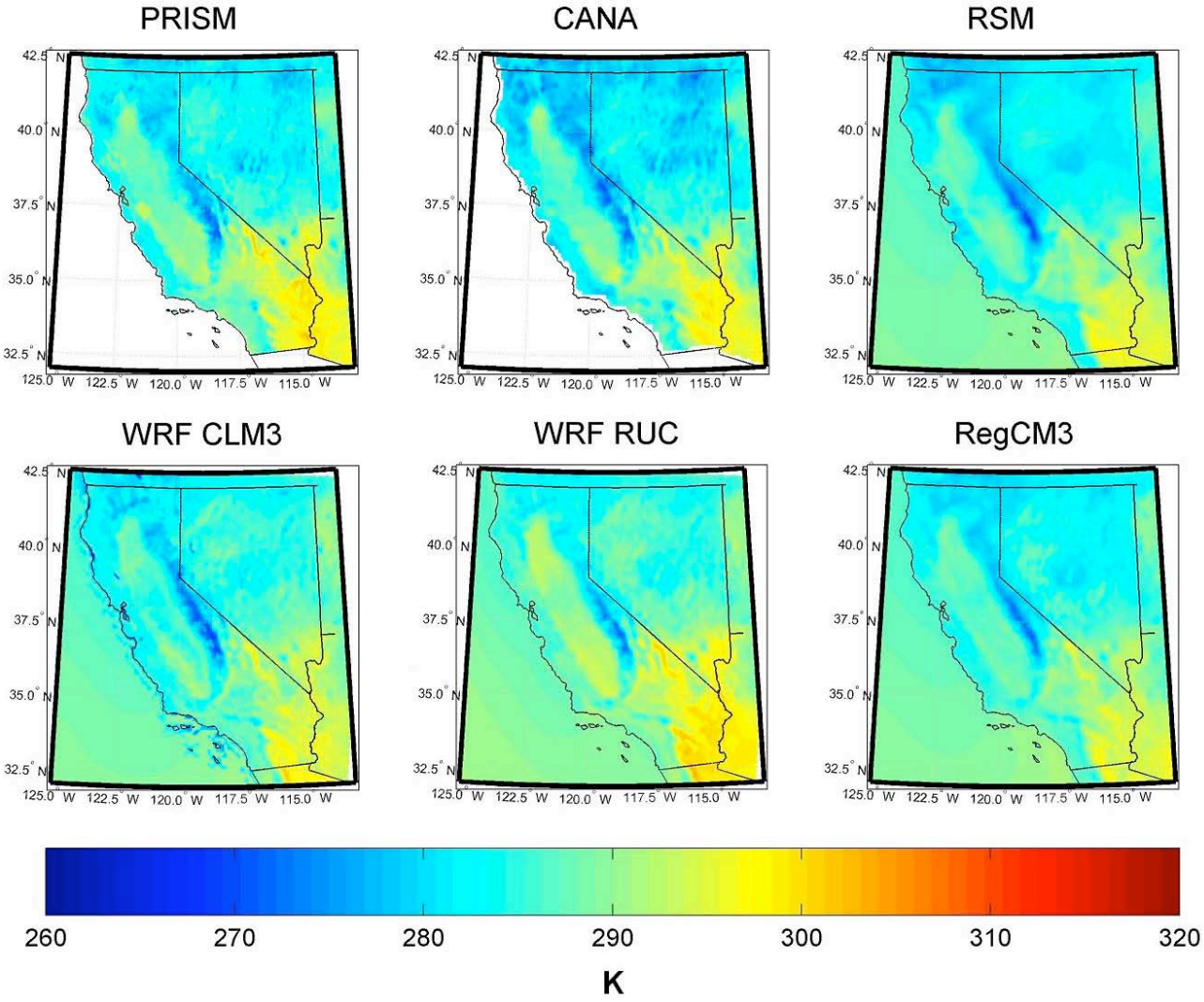


Difference relative to PRISM in Maximum 2-m air temperature during June-August.

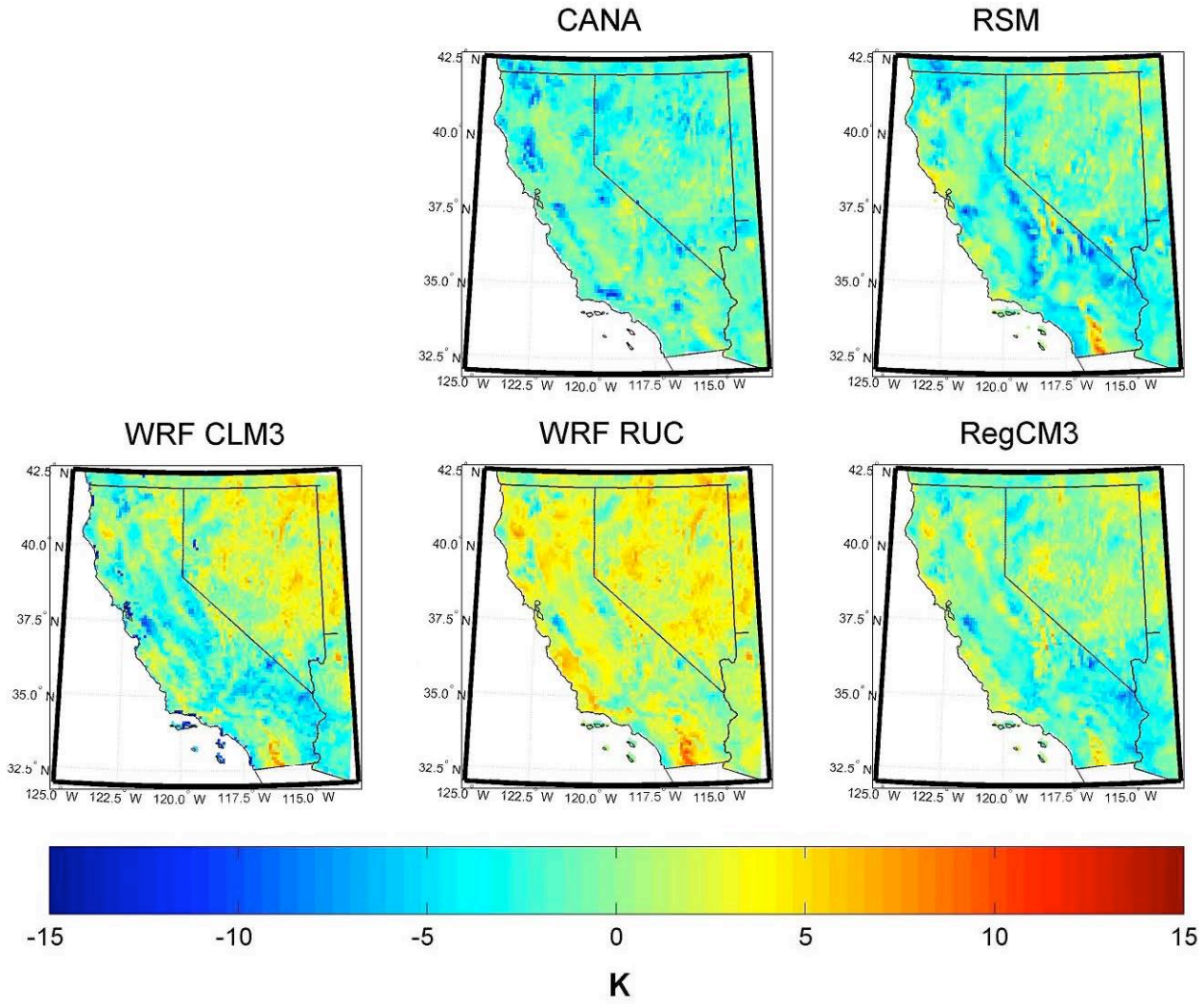


Summer Minimum Temperature

June - August

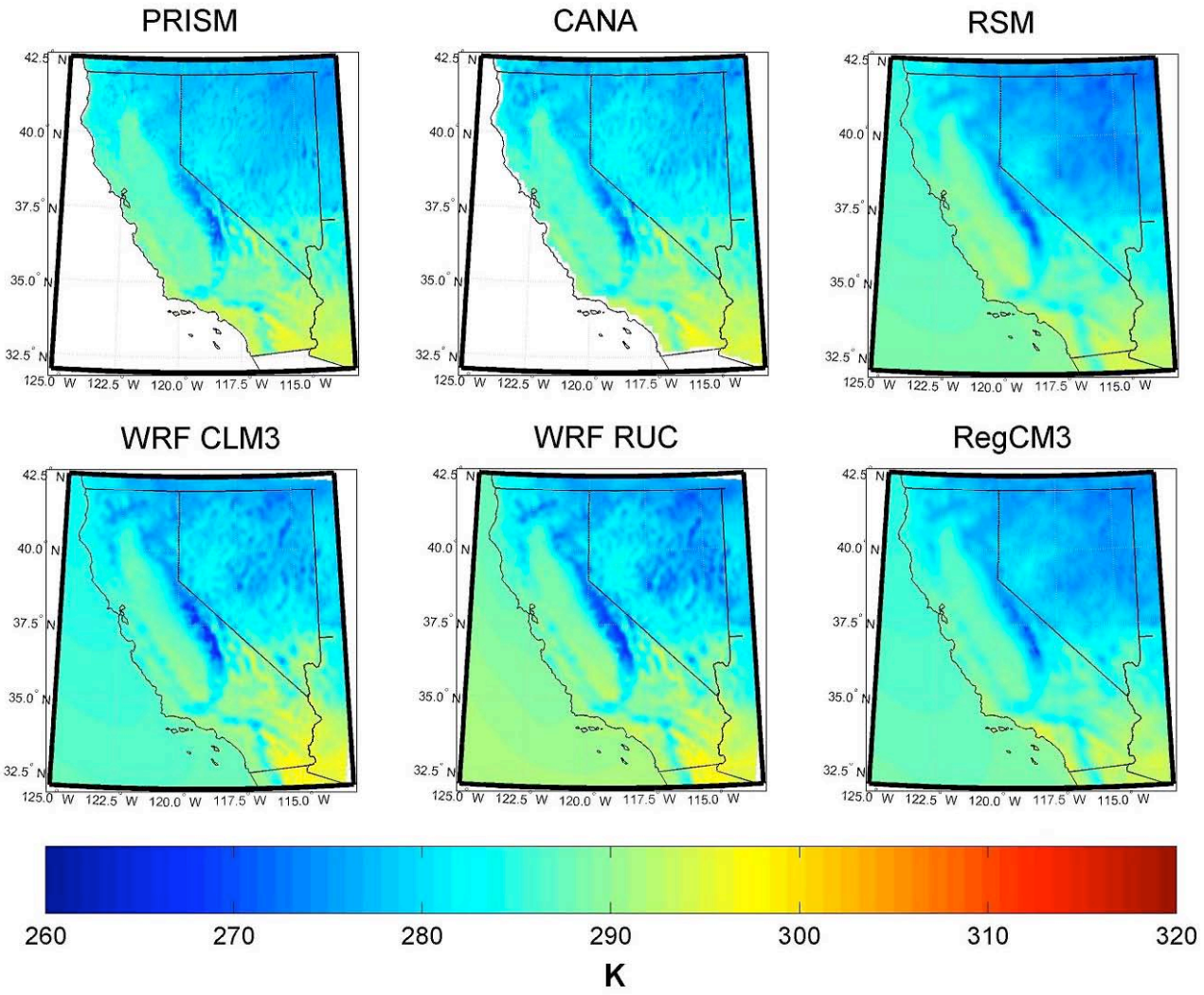


Difference relative to PRISM in Minimum 2-m Air Temperature during June-August.

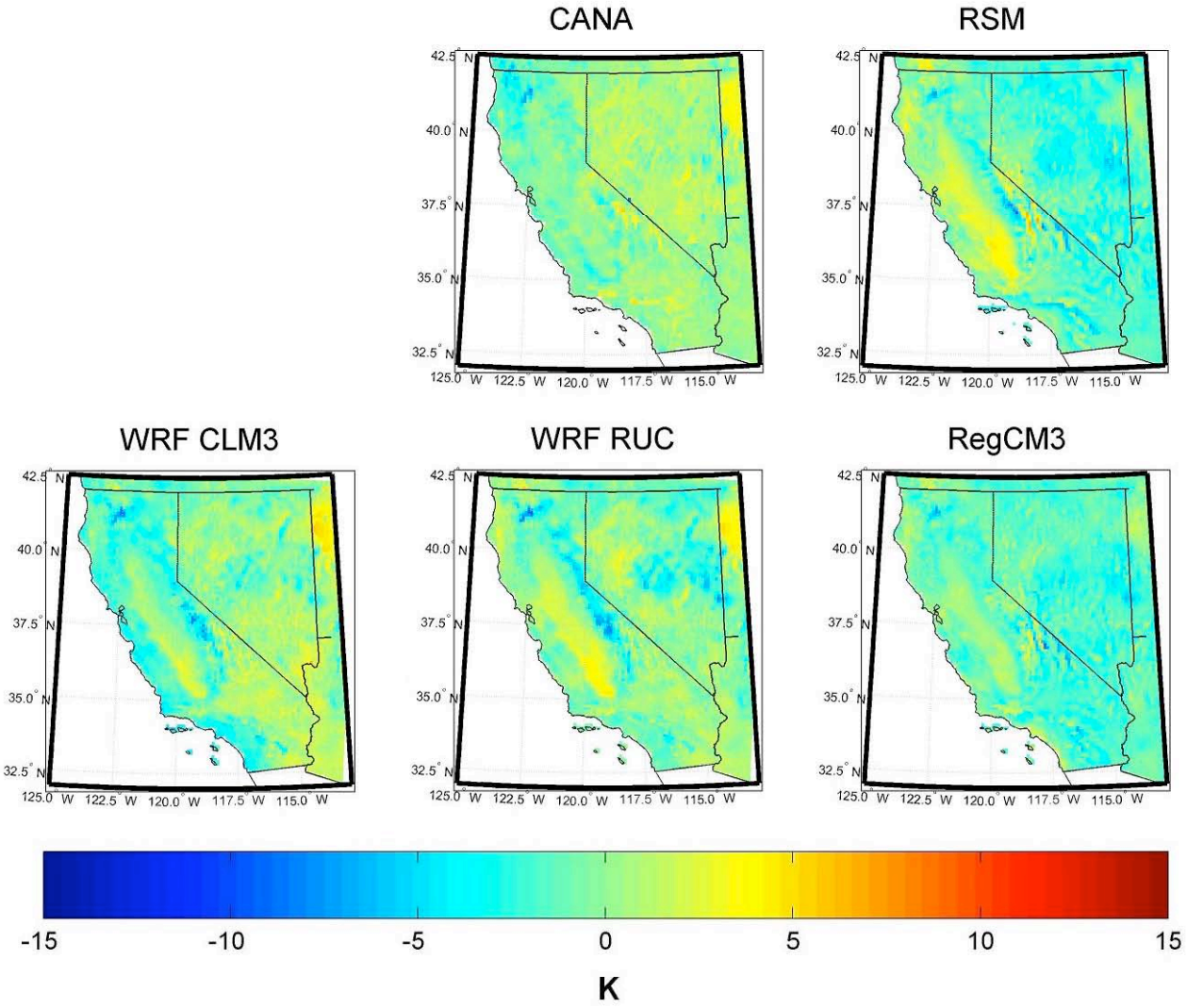


Winter Maximum Temperature

December - February

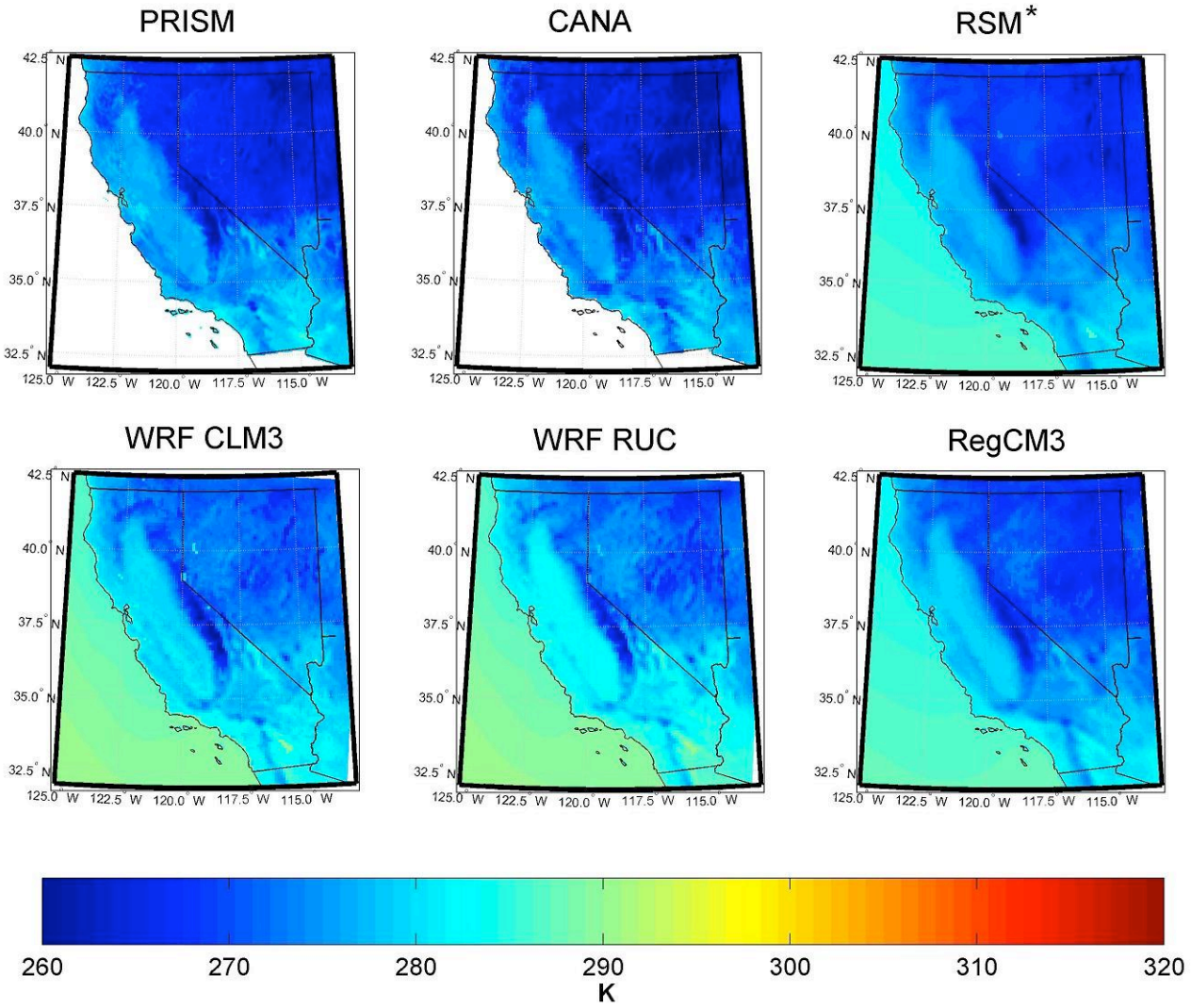


Difference relative to PRISM in Maximum 2-m air temperature during December-February

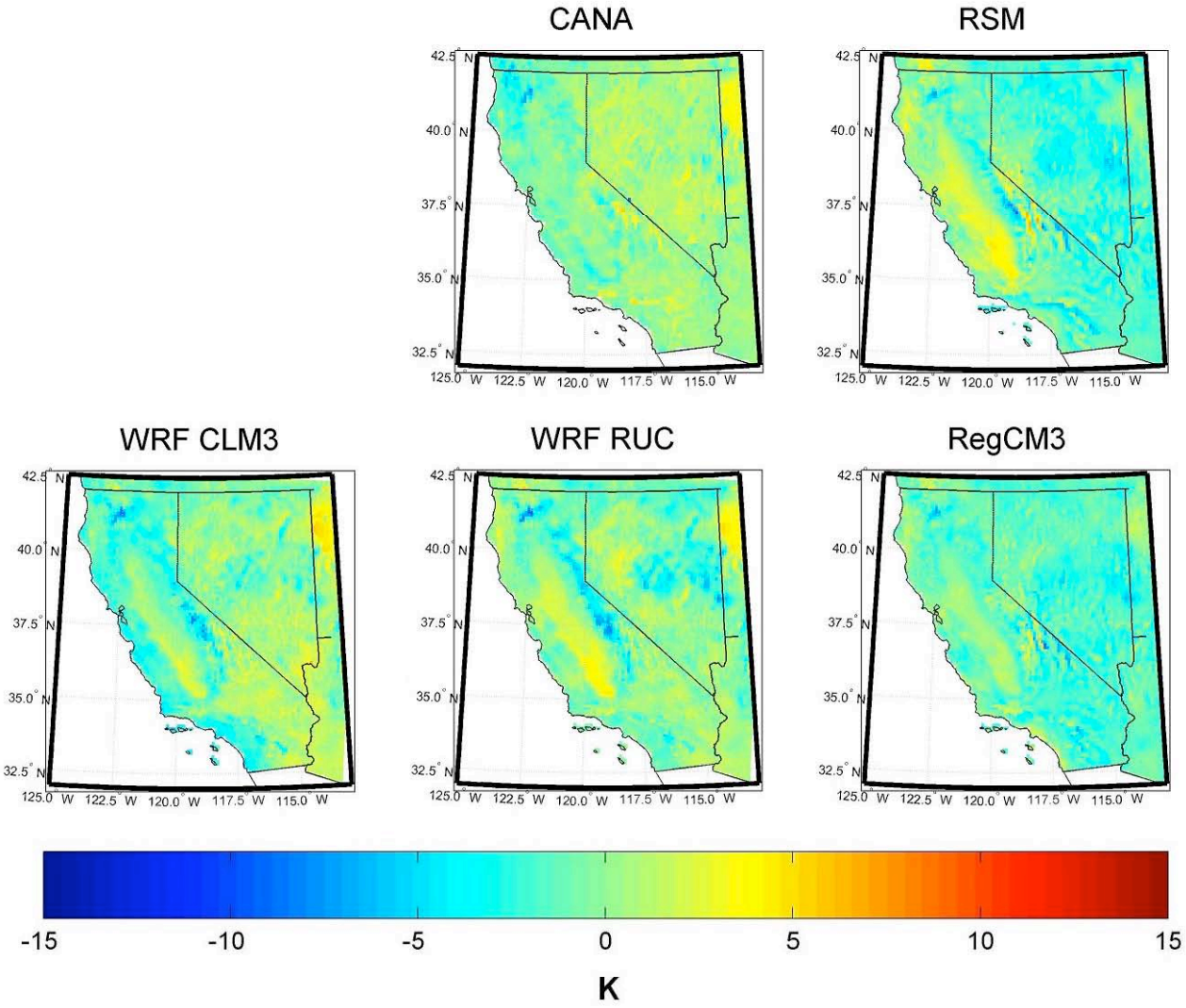


Winter Minimum Temperature

December - February

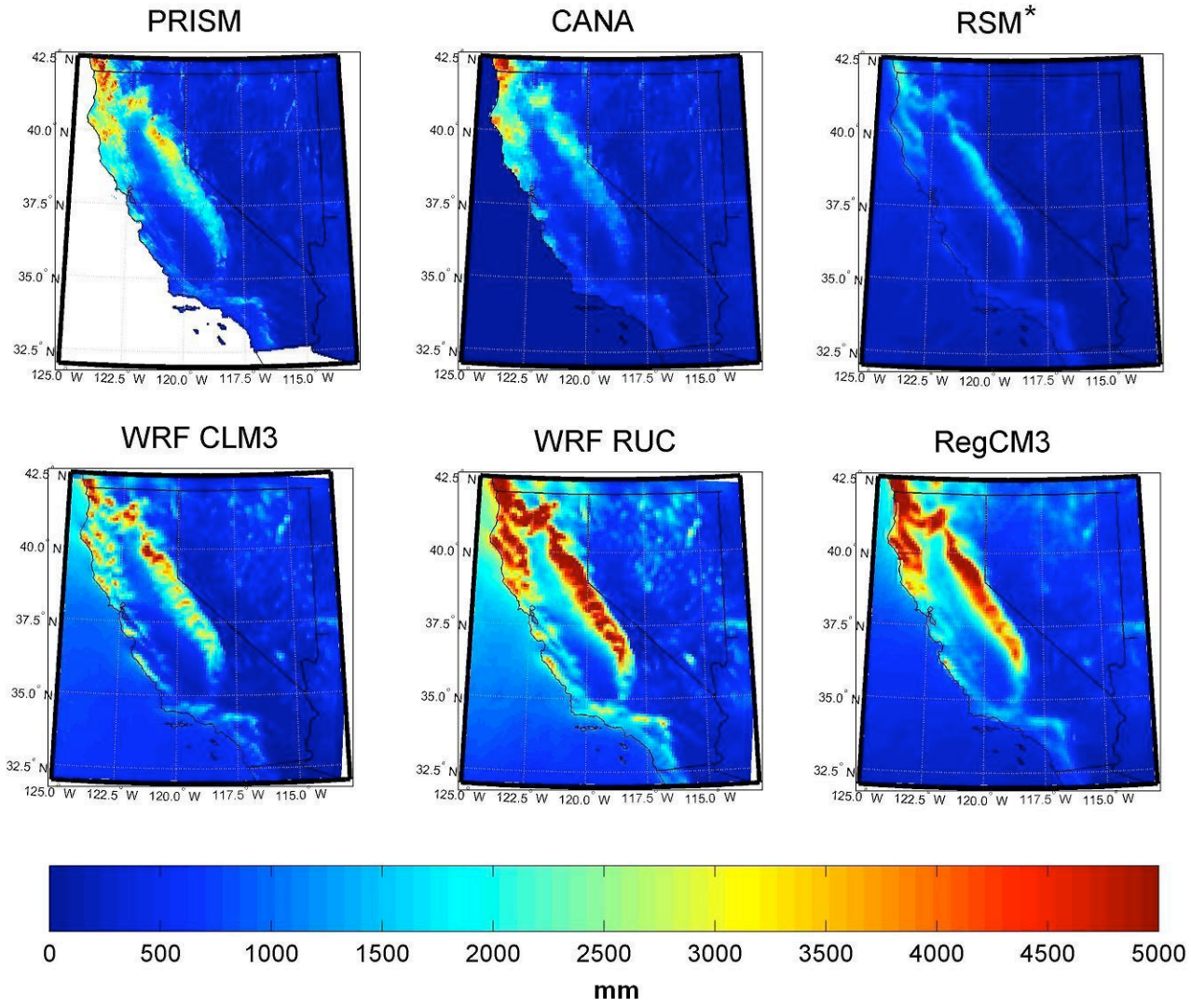


Difference relative to PRISM in Minimum 2-m air temperature during December-February.

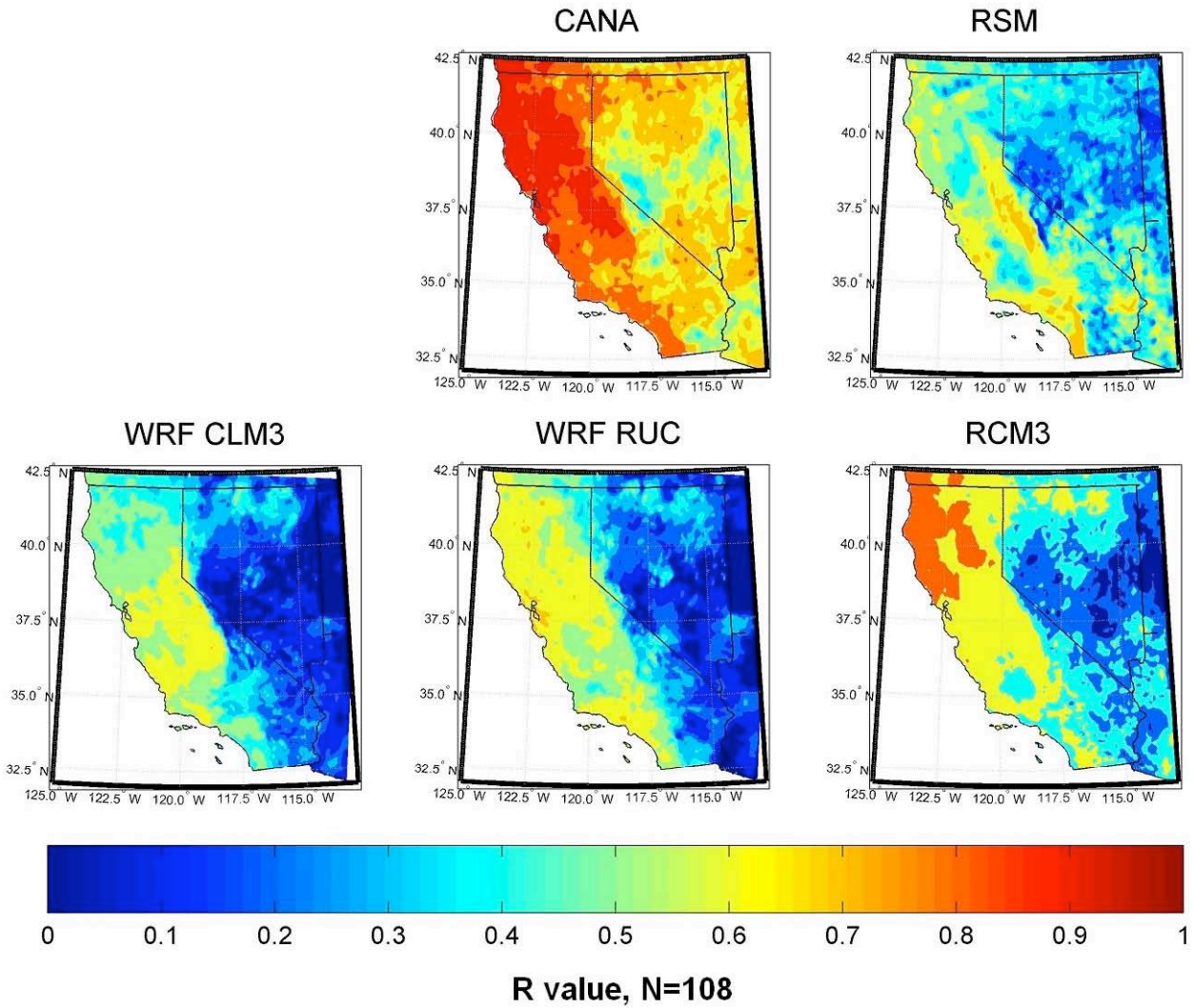


Cumulative Precipitation

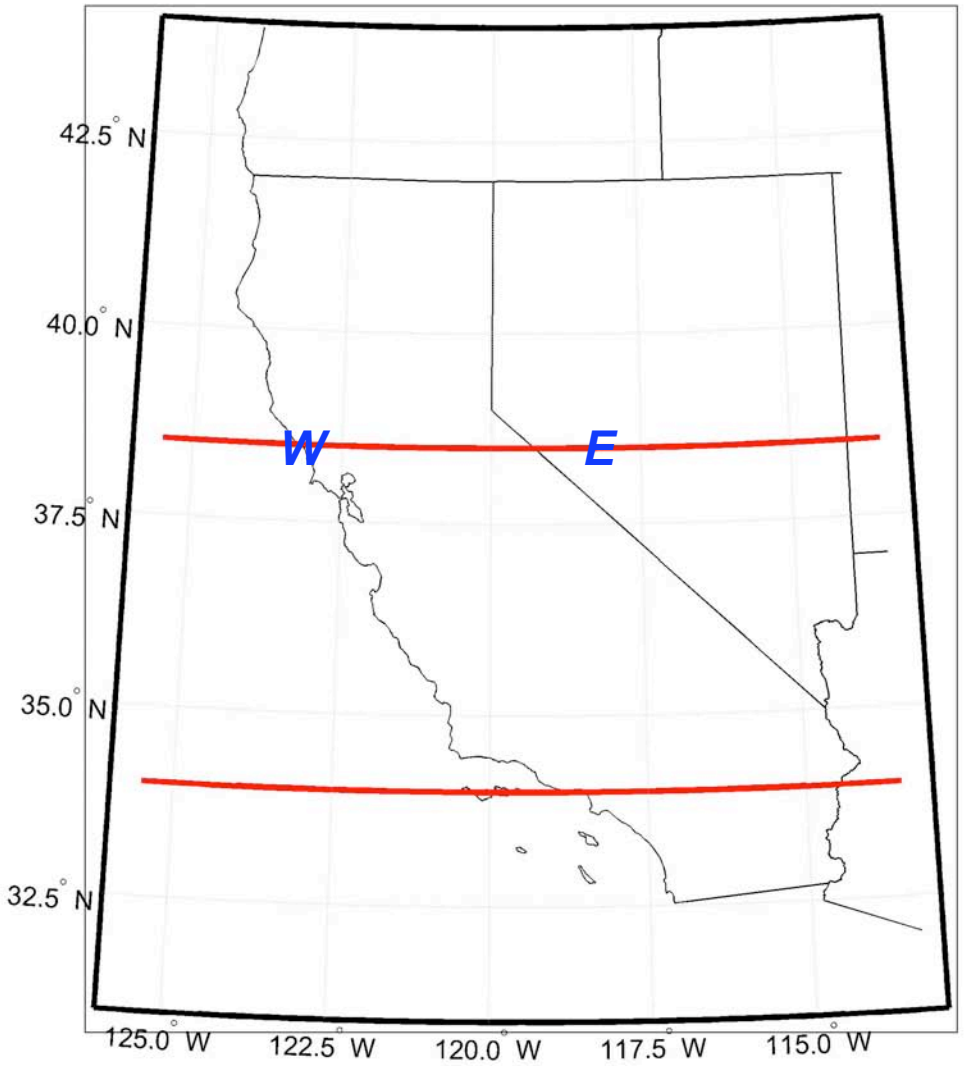
November - March



Cumulative November – March Precipitation Correlation to PRISM.

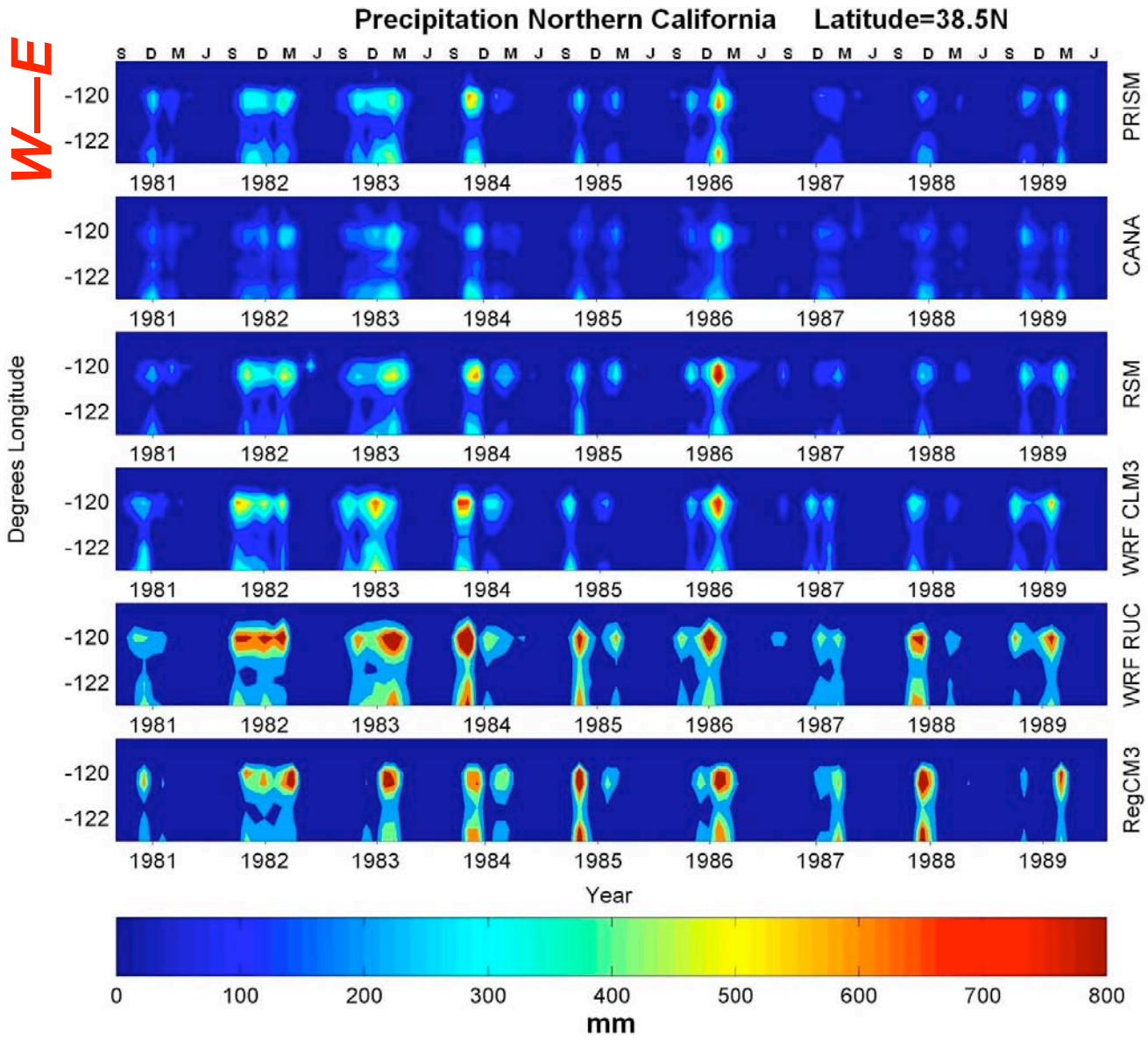


Transect Analysis at 38.5 N and 34 N

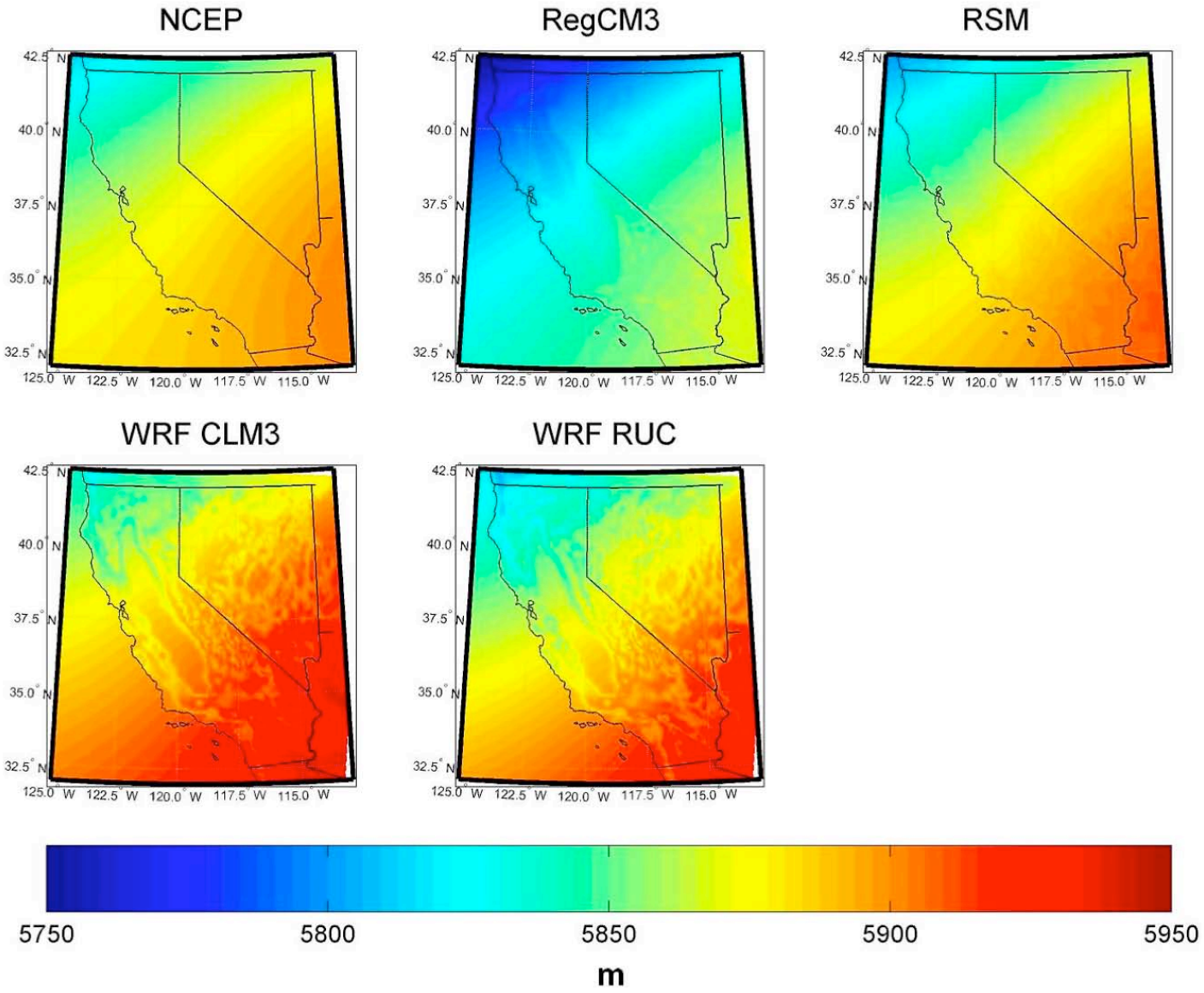


]

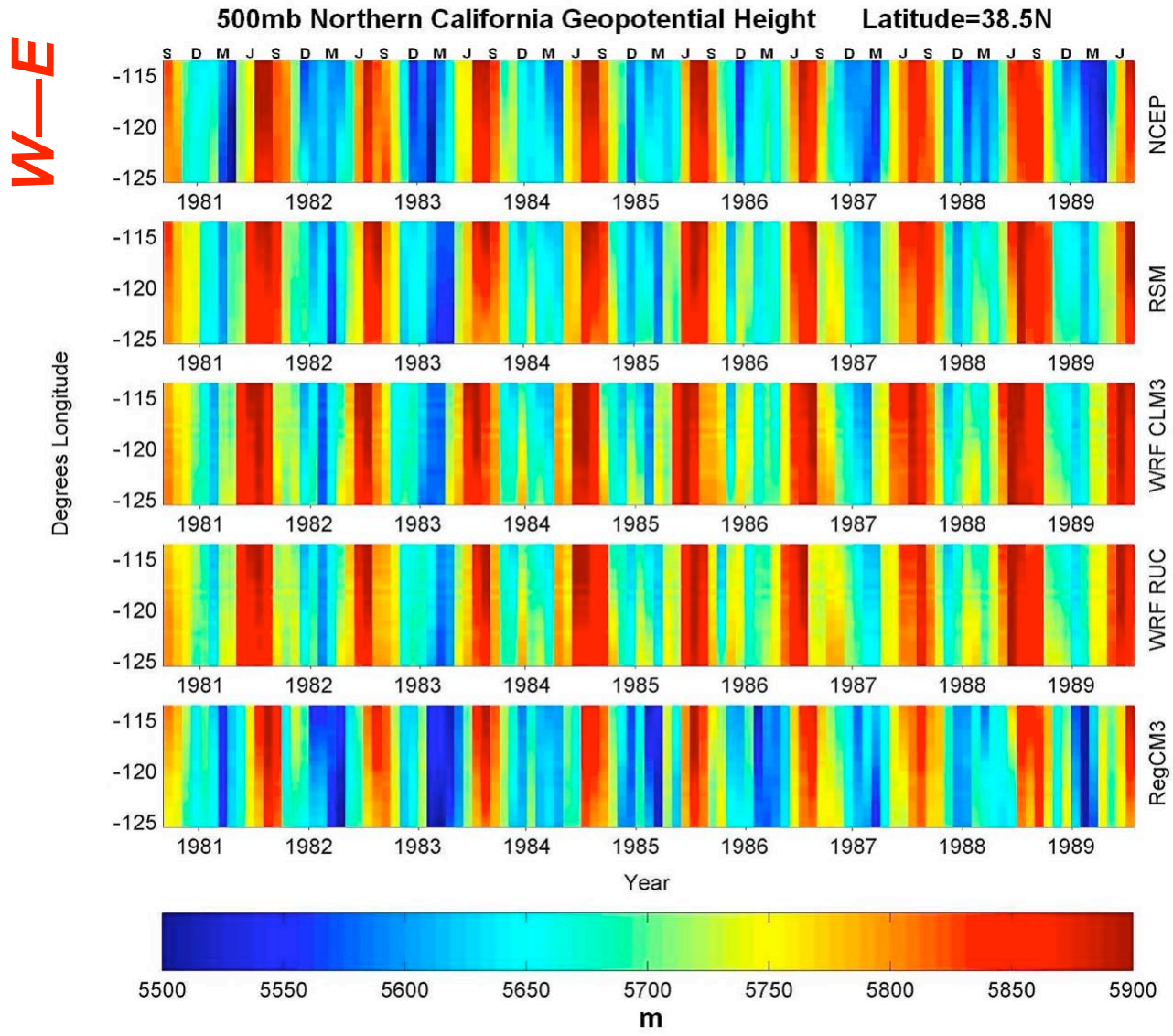
Time-Space plots of Precipitation at 38.5N.
West-East Section across the Russian and American River Basins



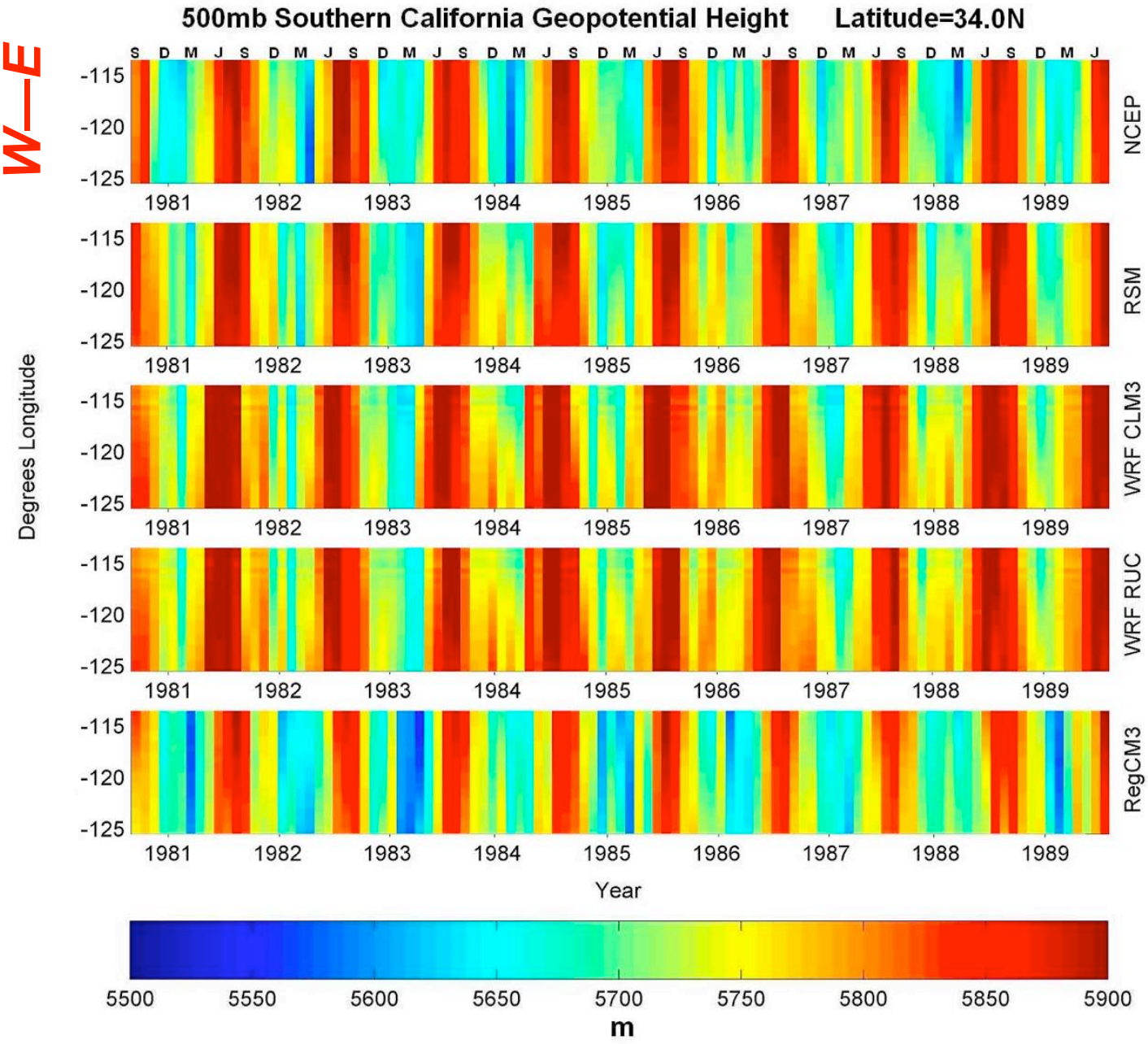
January 500hPa Geopotential Heights

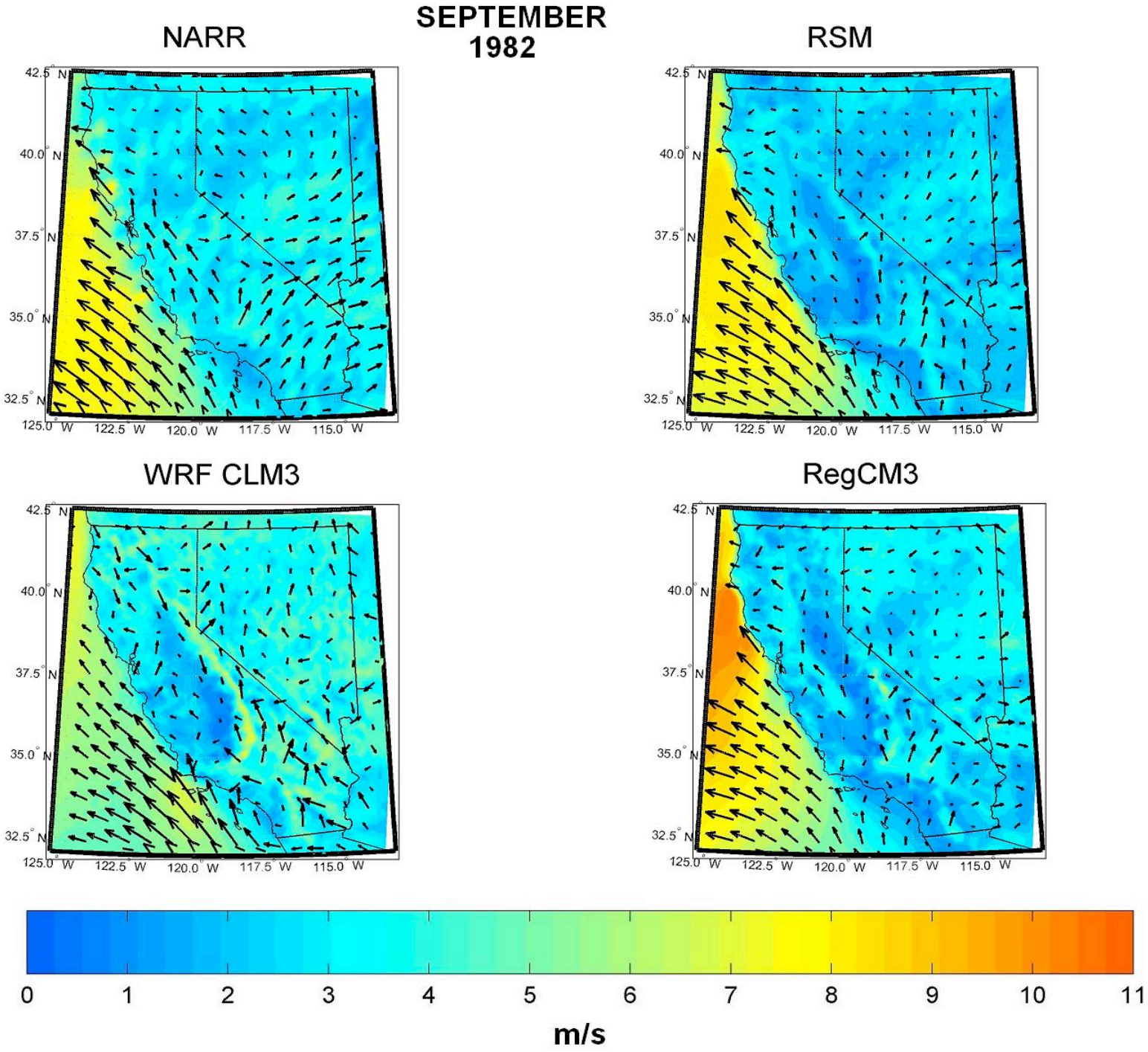


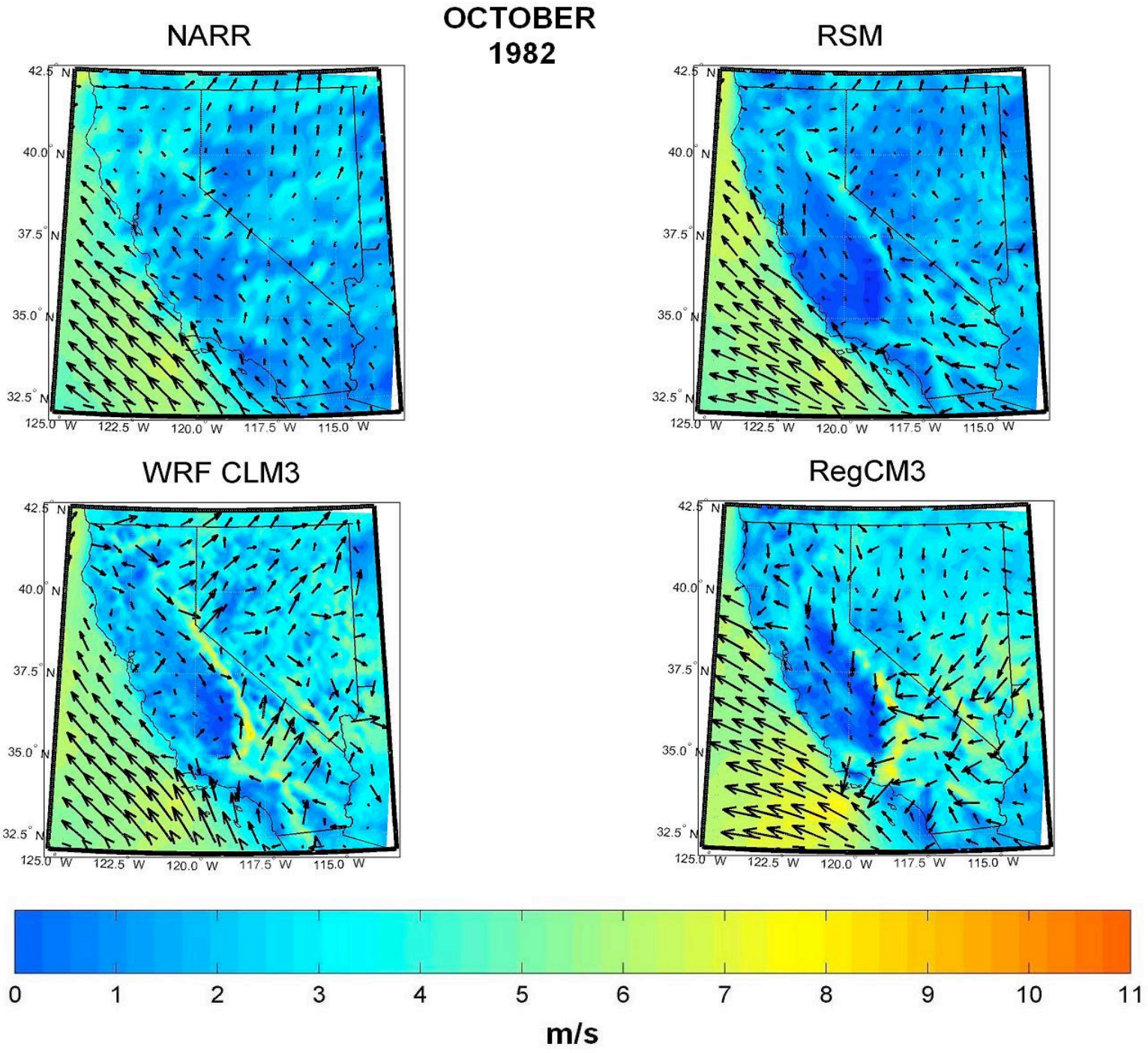
500 hPa Geopotential Heights at 38.5N. West-East X-Section with Russian and American River Basins

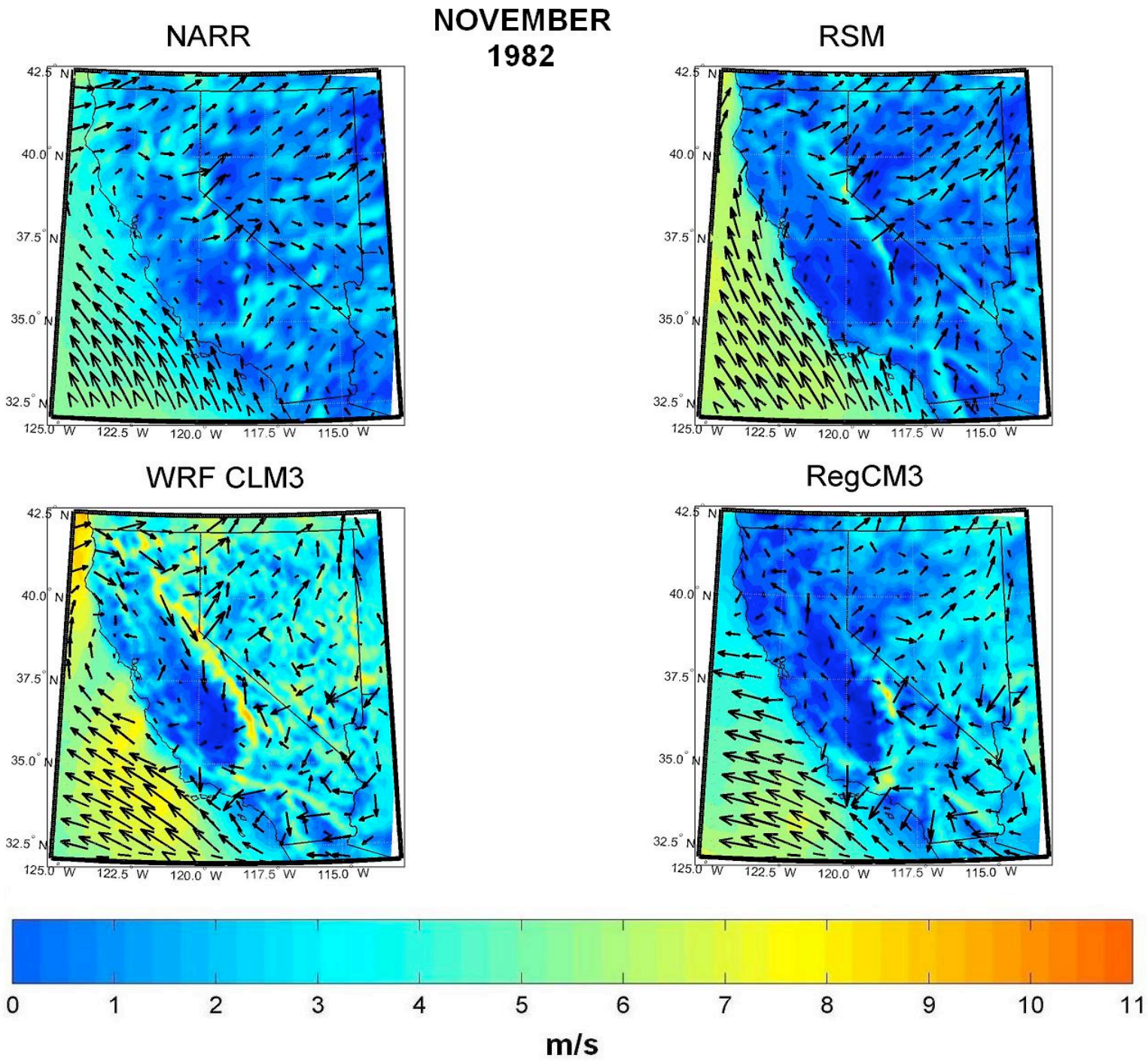


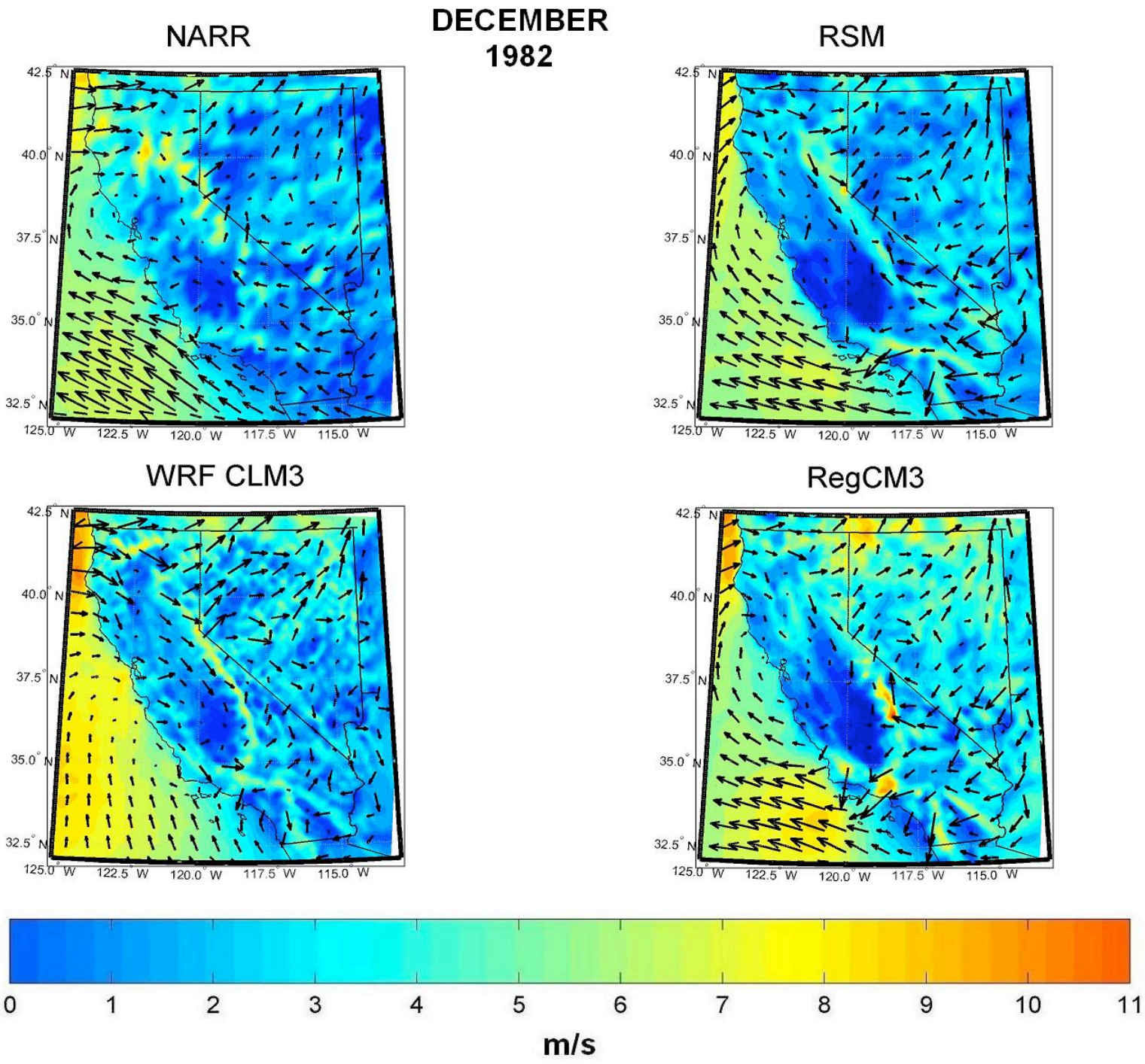
500 hPa geopotential heights at 34N.

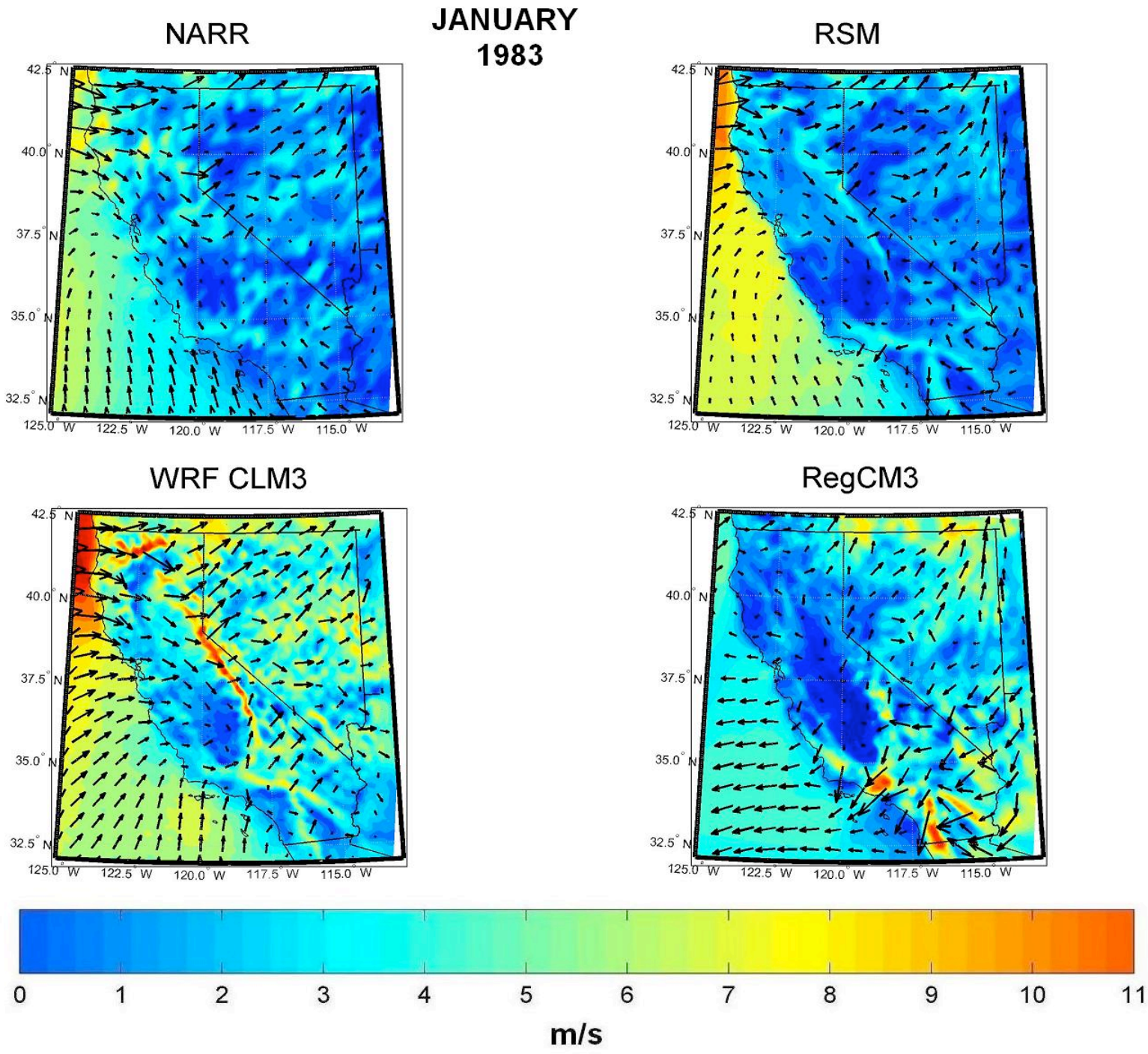



SEPTEMBER
1982
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s


OCTOBER
1982
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s

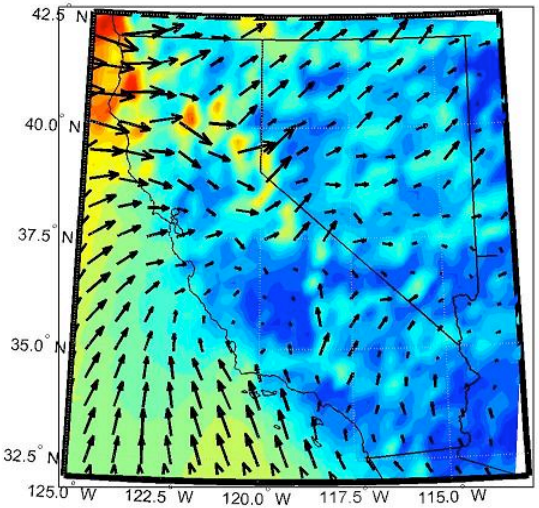

NOVEMBER
1982
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s


DECEMBER
1982
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s

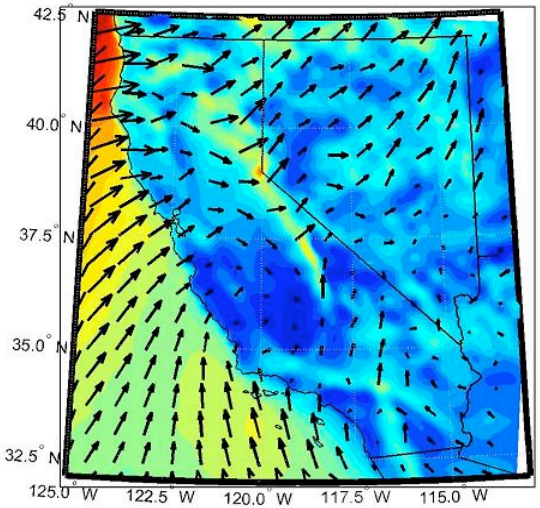

JANUARY
1983
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s

FEBRUARY
1983

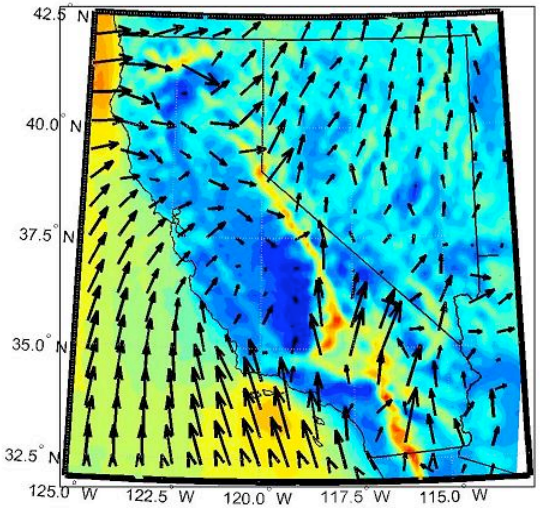
NARR



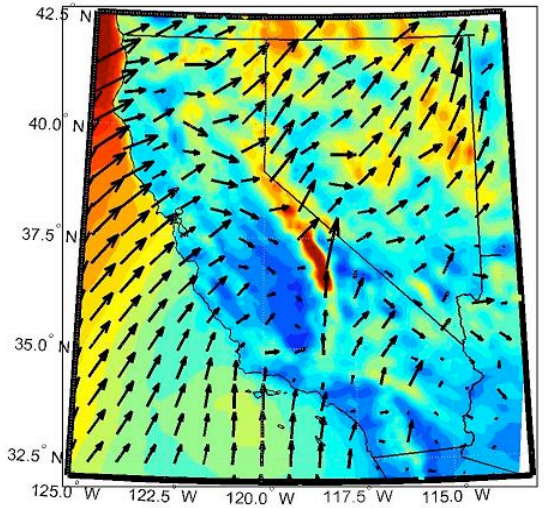
RSM

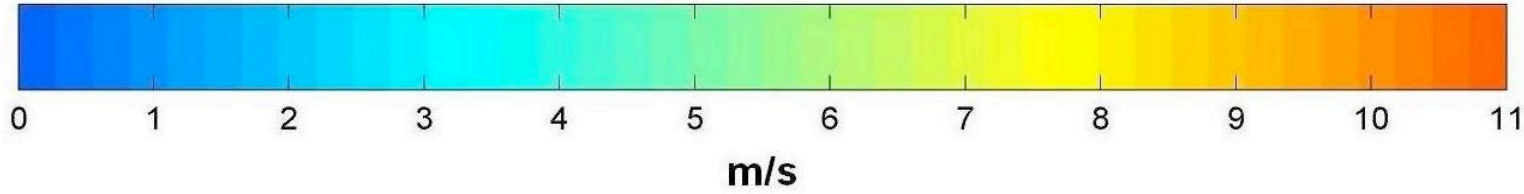


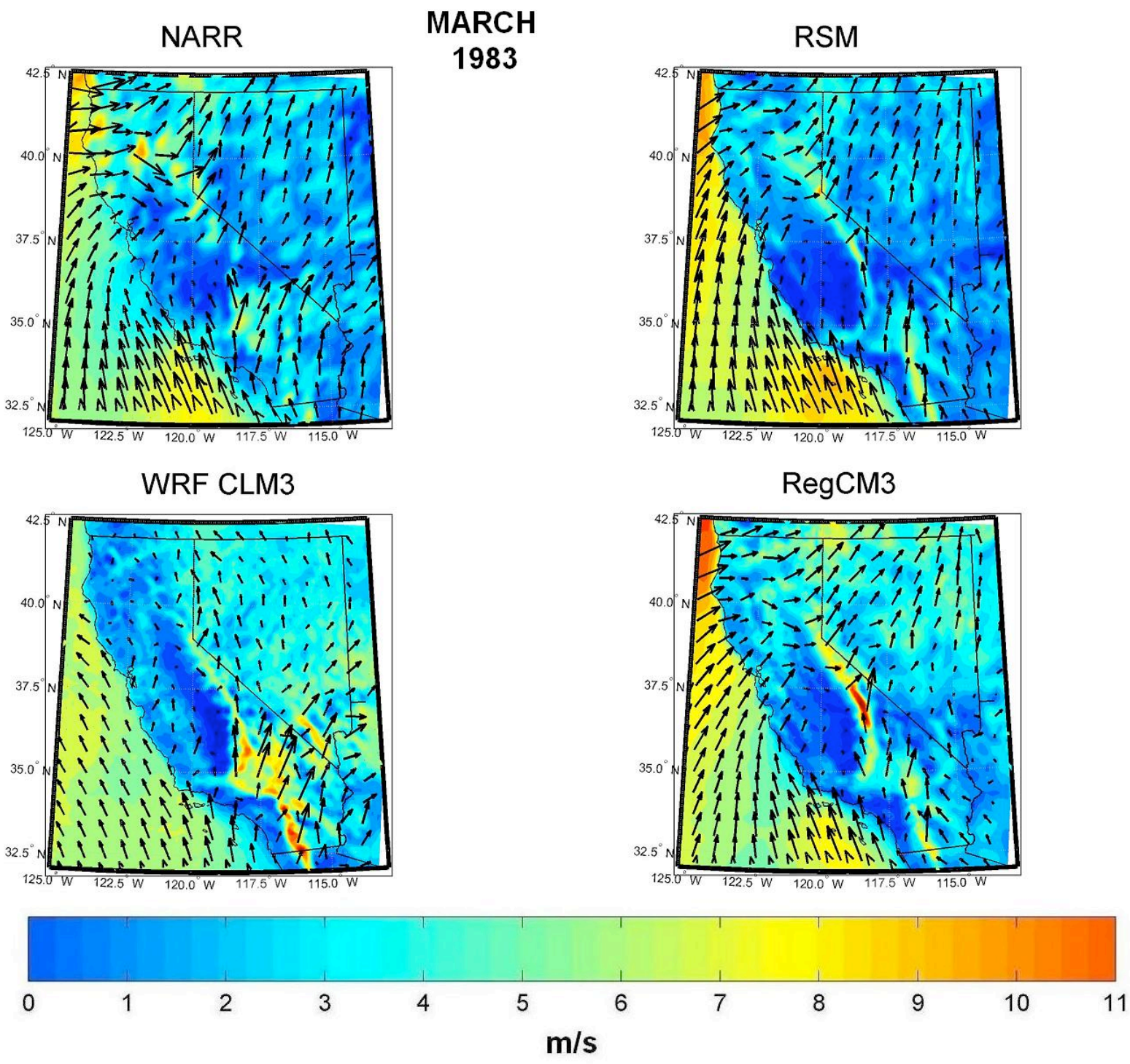
WRF CLM3

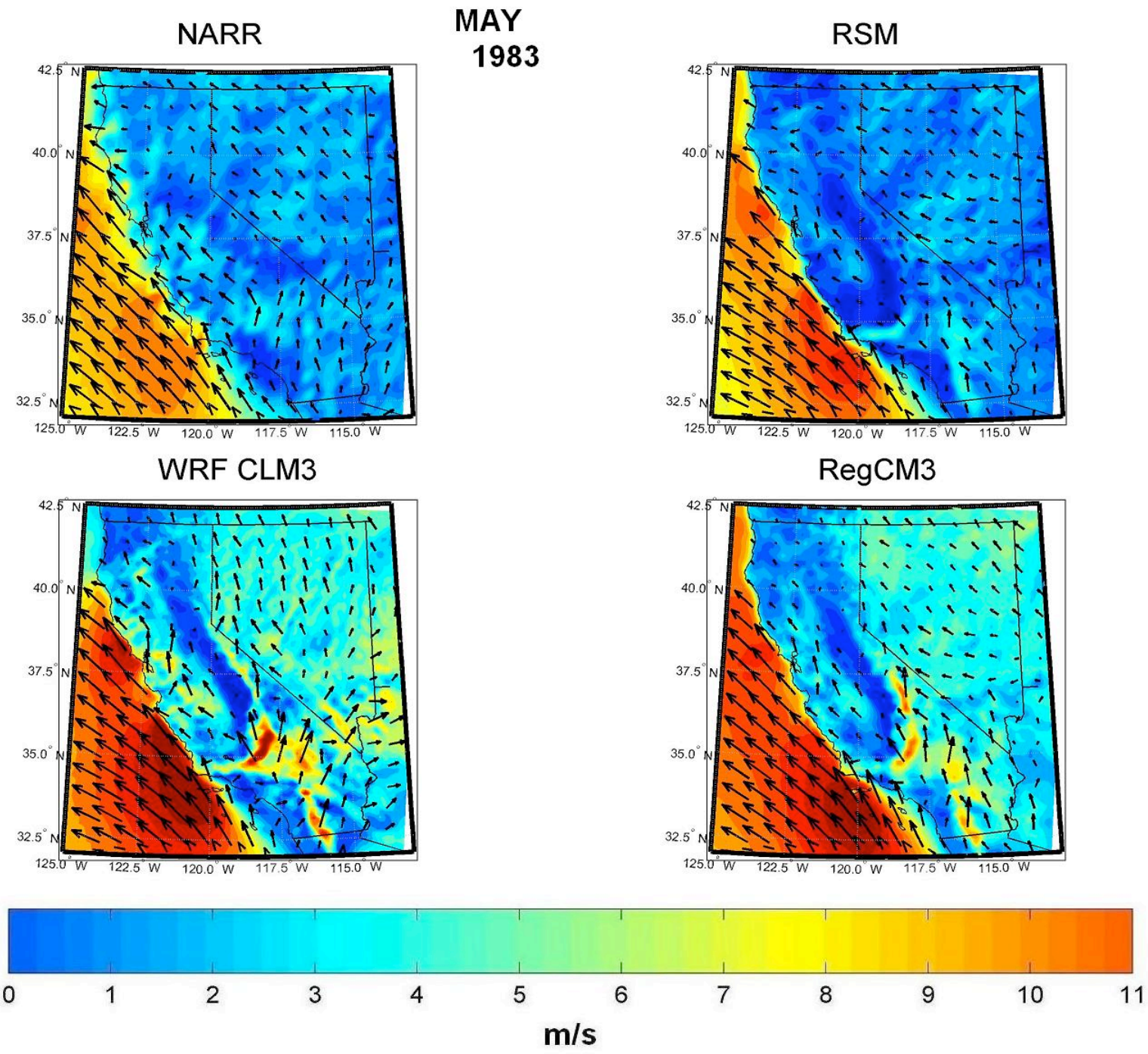


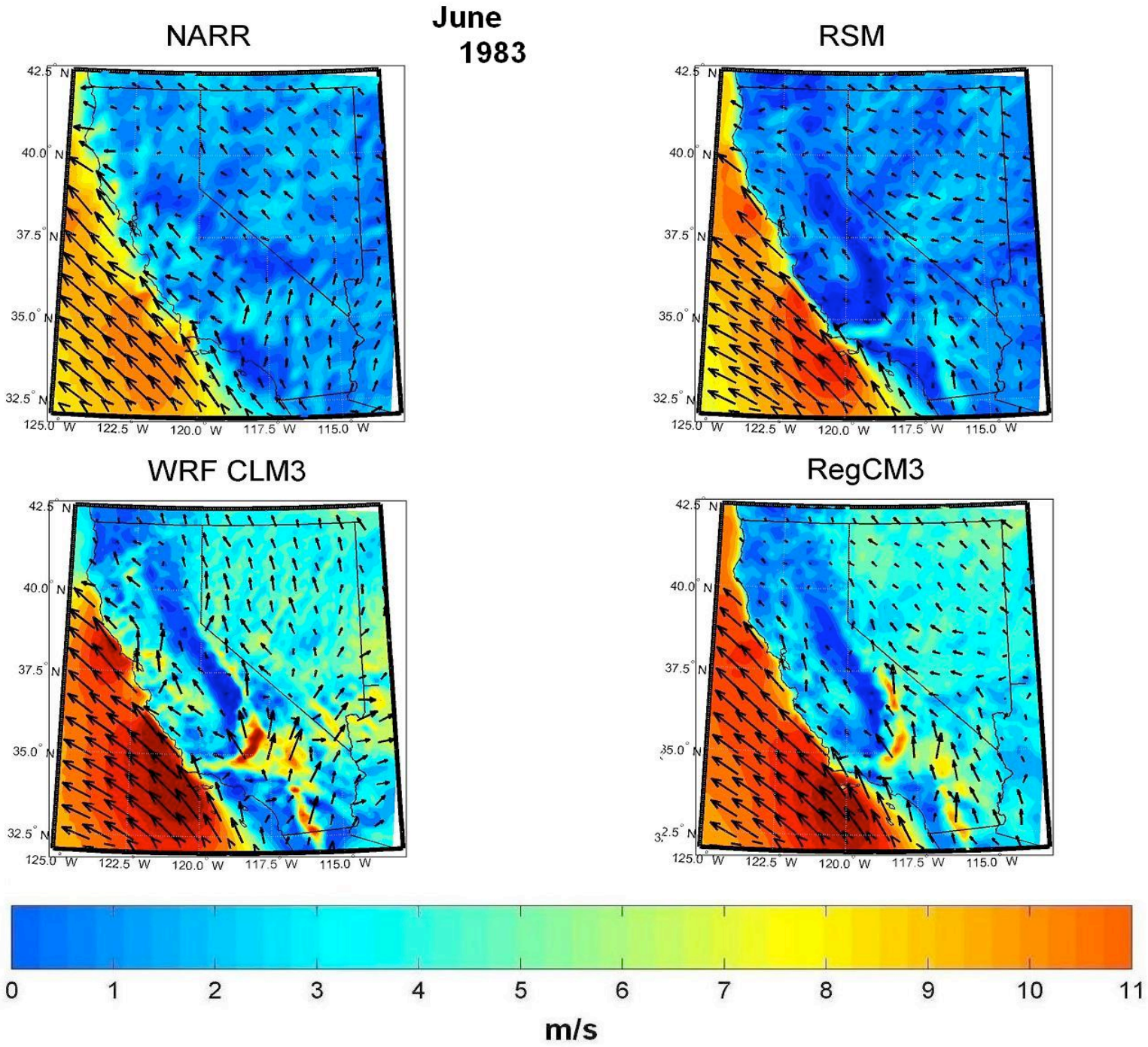
RegCM3

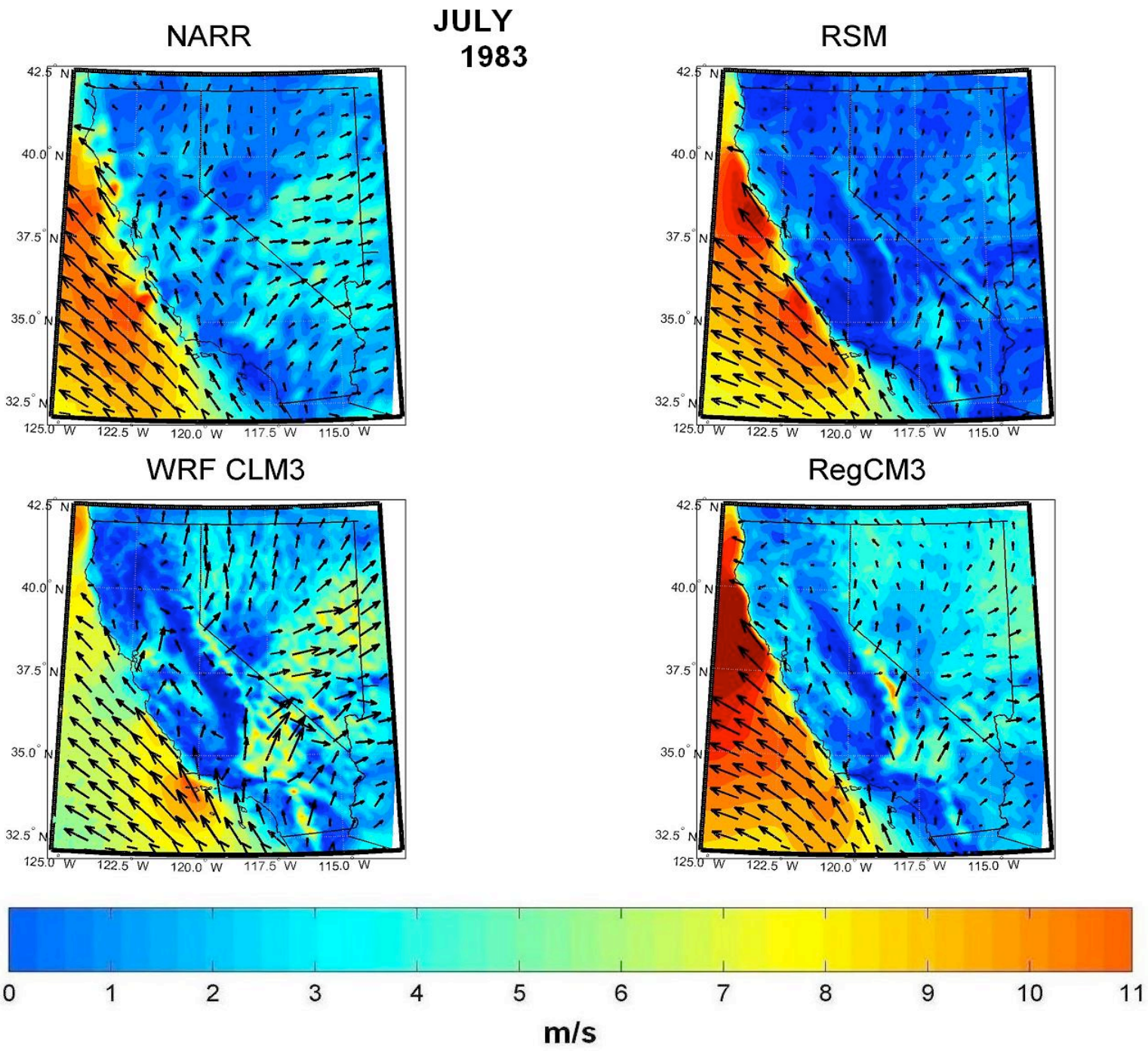


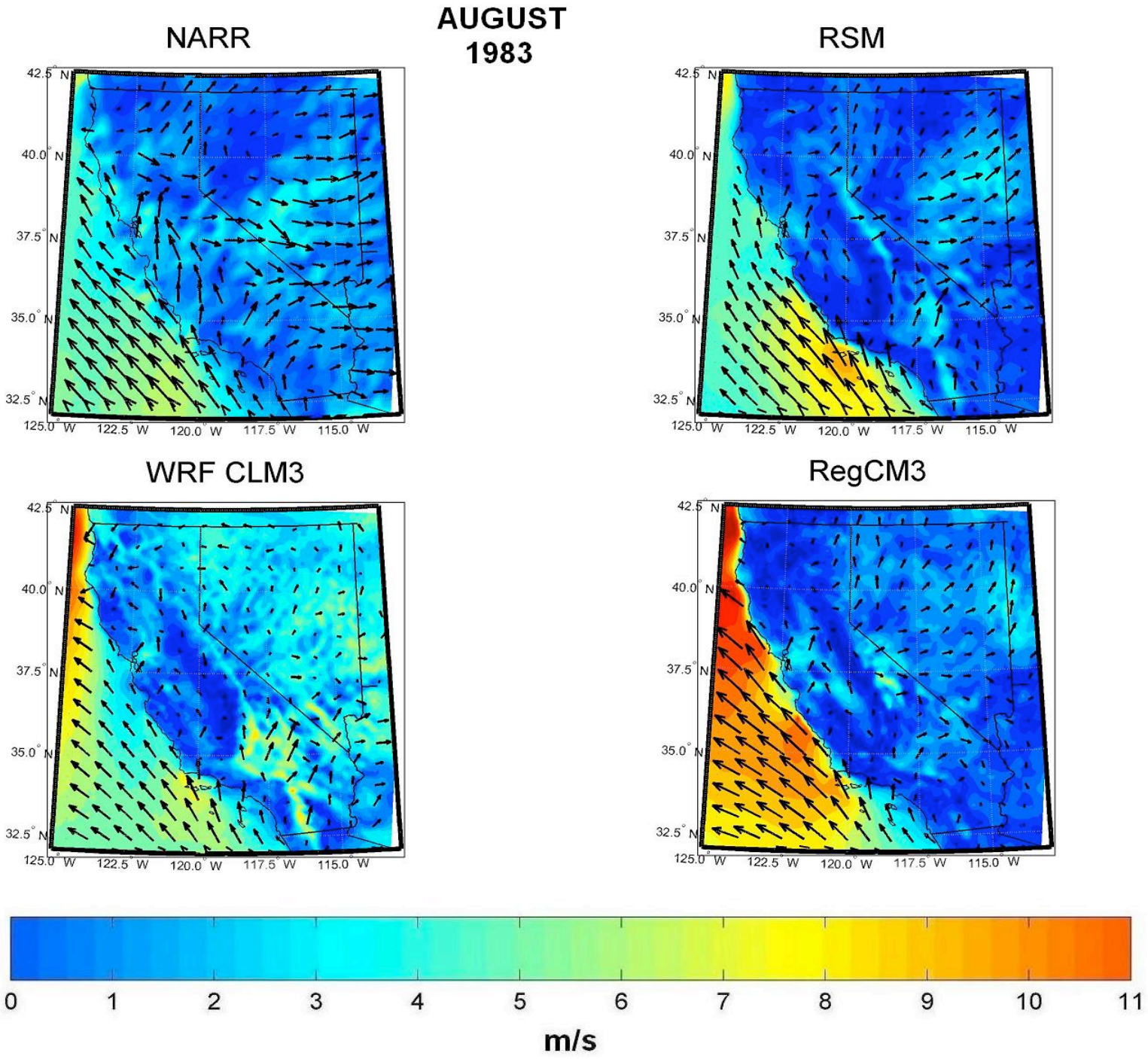



MARCH
1983
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s

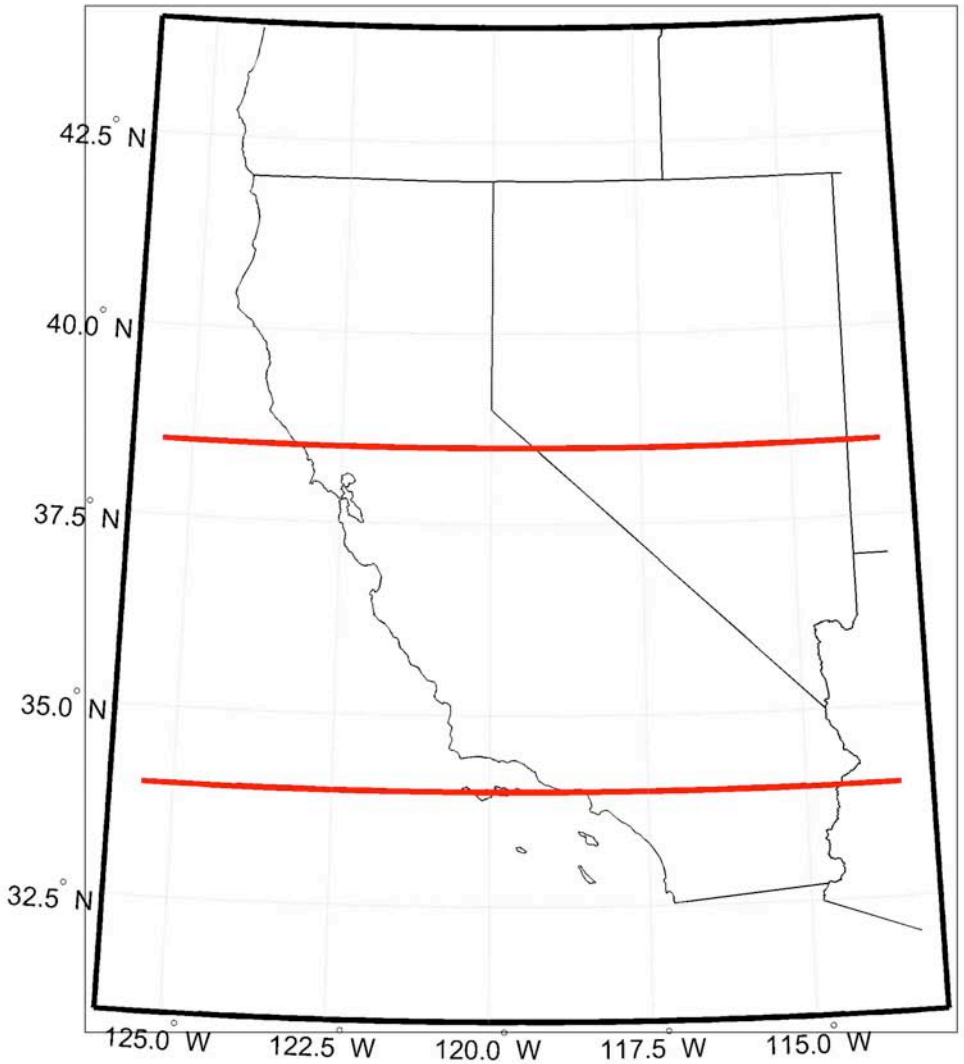

MAY
1983
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s


June
1983
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s

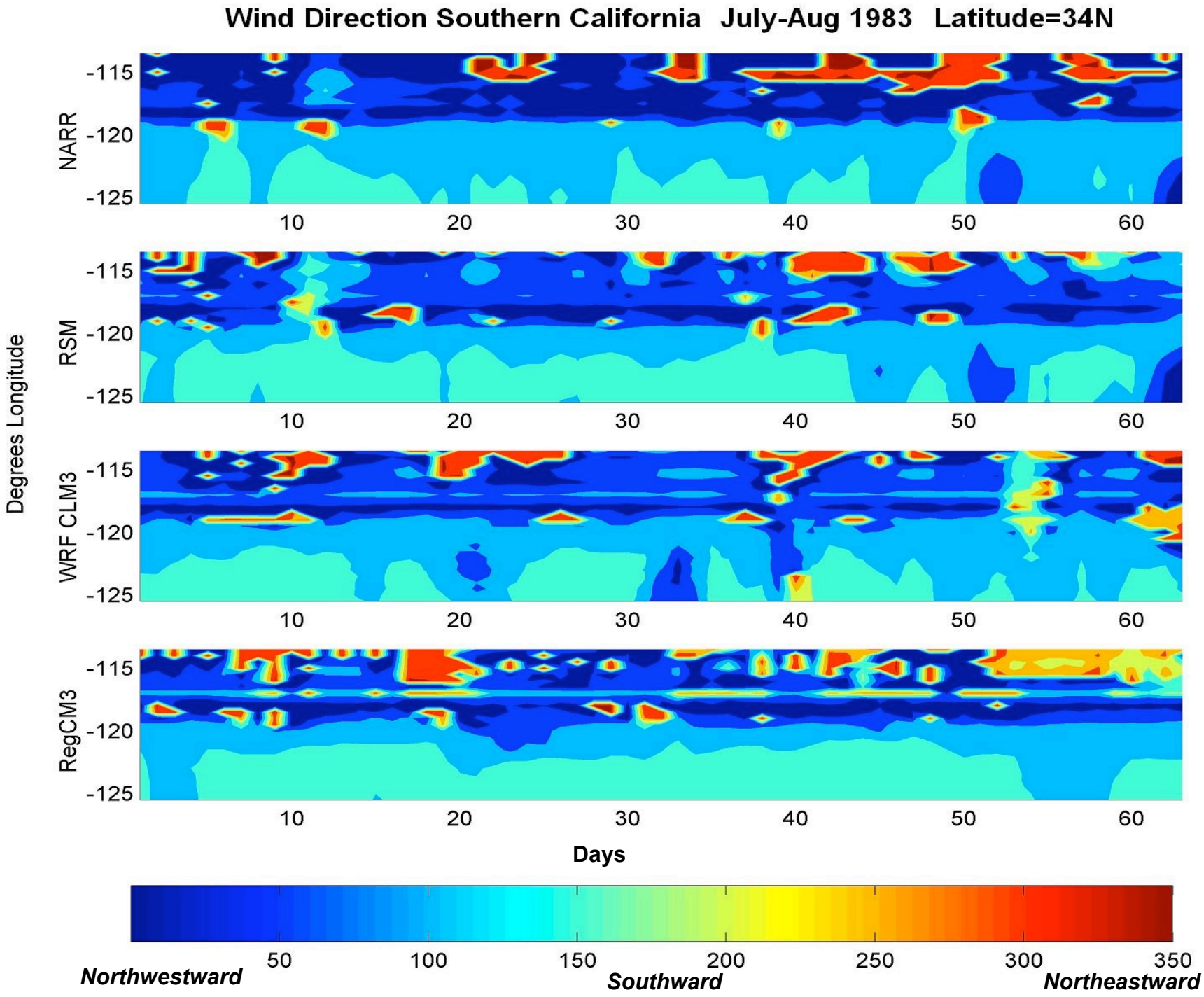

JULY
1983
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s

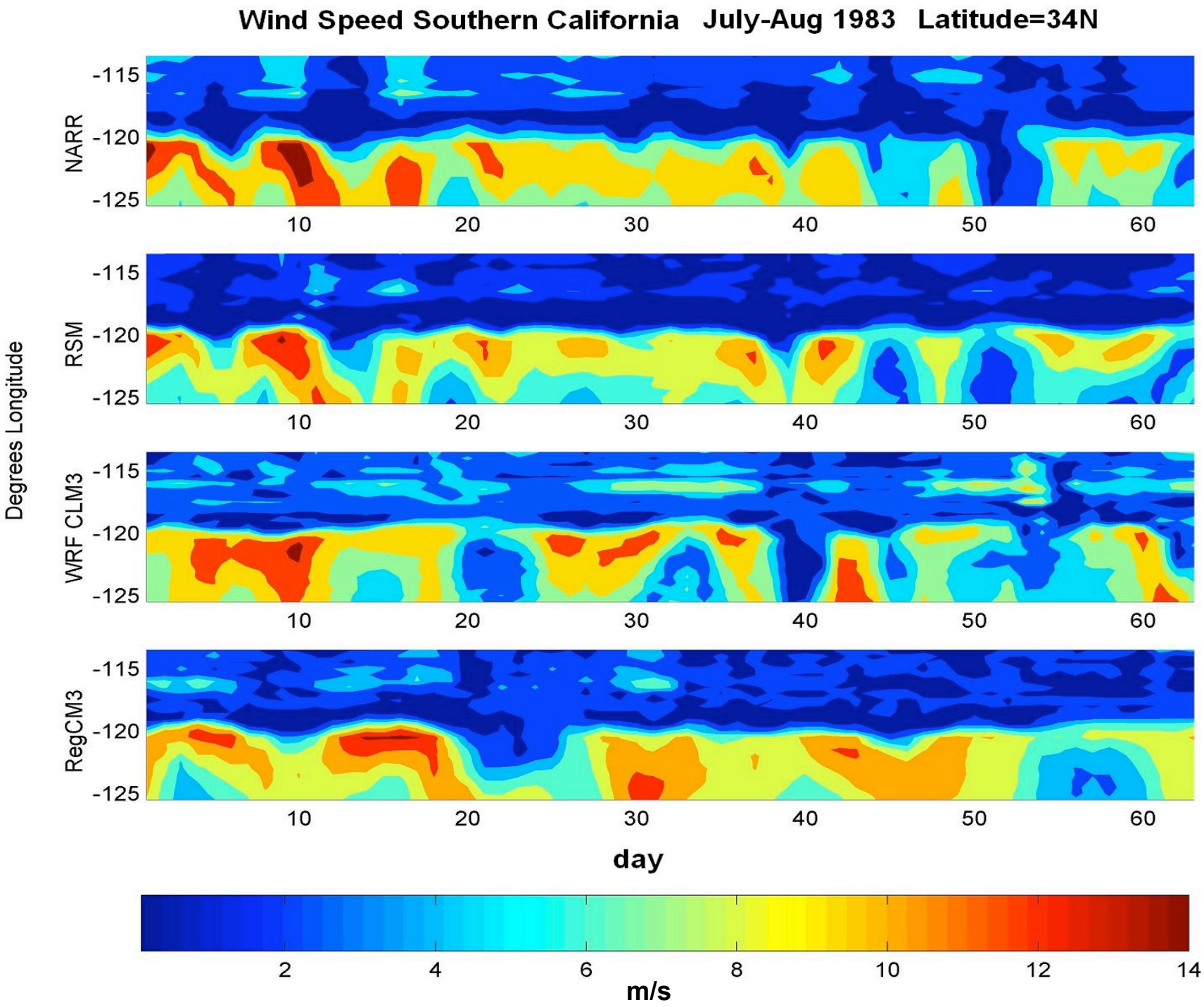

AUGUST
1983
NARR
RSM
WRF CLM3
RegCM3
42.5° N
40.0° N
37.5° N
35.0° N
32.5° N
125.0° W
122.5° W
120.0° W
117.5° W
115.0° W
0
1
2
3
4
5
6
7
8
9
10
11
m/s

Transect Analysis at 38.5 N and 34 N



]


Wind Direction Southern California July-Aug 1983 Latitude=34N
Degrees Longitude
NARR
RSM
WRF CLM3
RegCM3
-115
-120
-125
10
20
30
40
50
60
Days
50
100
150
200
250
300
350
Northwestward
Southward
Northeastward


Wind Speed Southern California July-Aug 1983 Latitude=34N
Degrees Longitude
NARR
RSM
WRF CLM3
RegCM3
-115
-120
-125
10
20
30
40
50
60
day
2
4
6
8
10
12
14
m/s

Next Steps:
Regional Climate Change Projections

- **Simulation of the historical climate with the IPCC Global Climate Models as input forcing.**

- **Begin "time slice" simulations of early, mid, and late century California climates at 10 km resolution.**

- **Expand number of model ensemble members and further coordinate simulations with other groups.**

- **New studies have begin with a very high-resolution, multi-grid Coastal Ocean Circulation Model and WRF.**

Concluding Remarks

- Downscaling is only as good as the large-scale forcing
- Downscaling has limitations, each model has unique and in numerous cases similar strengths and weaknesses.
- The Dynamic Models shown are state-of-the-art, yet still have problems simulating precipitation and other variables.
- The CANA technique performs at least as well as the dynamic models. BUT - very for a few variables: Temperature, Precipitation
- Dynamic Models do well simulating large-scale features such as the 500 mb geopotential heights, BUT subgrid parameterizations continue to be problematic.